EXHIBIT 150
PART 3

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B111: Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock

CFR Section(s): 46 CFR 56.60-1(b)

Standards Body: American Society for Testing and Materials

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Standard Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock[1]

This standard is issued under the fixed designation B 111; 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. Replaces WW-T-756. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification[2] covers seamless tube and ferrule stock of copper and various copper alloys up to 3⅛ in., inclusive, in diameter, for use in surface condensers, evaporators, and heat exchangers. Tubes for this application are normally made from the following coppers or copper alloys:[3]

Copper or Copper Alloy UNS No.	Previously Used Designation	Type of Metal
C10100	OFE	Oxygen-free electronic
C10200	OF[A]	Oxygen-free without residual deoxidants
C10300	...	Oxygen-free, extra low phosphorus
C10800	...	Oxygen-free, low phosphorus
C12000	DLP[A]	Phosphorized, low residual phosphorus
C12200	DHP[A]	Phosphorized, high residual phosphorus
C14200	DPA[A]	Phosphorized, arsenical
C19200	...	Phosphorized, 1 % iron
C23000	...	Red Brass
C28000	...	Muntz Metal
C44300	...	Admiralty Metals, B, C, and D
C44400		
C44500		
C60800	...	Aluminum Bronze
C61300	...	...
C61400	...	Aluminum Bronze, D
C68700	...	Aluminum Brass, B
C70400	...	95-5 Copper-Nickel
C70600	...	90-10 Copper-Nickel
C71000	...	80-20 Copper-Nickel
C71500	...	70-30 Copper-Nickel
C71640	...	Copper-nickel-iron-manganese
C72200	...	...

[A] Designations listed in Classification B 224.

NOTE 1—A complete metric companion to Specification B 111 has been developed—B 111M; therefore, no metric equivalents are presented in this specification.

NOTE 2—**Warning:** Mercury is a definite health hazard in use and disposal. (See 12.1.)

1.2 The following safety hazards caveat pertains only to the test methods portion, Section 18, of this specification: *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:

2.1.1 *ASTM Standards:*

B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing[4]

B 154 Test Method for Mercurous Nitrate Test for Copper and Copper Alloys[4]

B 170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes[4]

B 224 Classification of Coppers[4]

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

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[6]

E 53 Test Methods for Chemical Analysis of Copper[7]

E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes[7]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[7]

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)[7]

E 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys[7]

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

E 243 Practice for Electromagnetic (Eddy Current) Examination of Copper and Copper-Alloy Tubes[8]

E 478 Test Methods for Chemical Analysis of Copper Alloys[7]

E 527 Practice for Numbering Metals and Alloys (UNS)[9]

3. Terminology

3.1 *Definitions:*

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.04 on Pipe and Tube.

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[2] For *ASME Boiler and Pressure Vessel Code* applications, see related Specification SB-111 in Section II of the Code.

[3] 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.

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

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

[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 03.03.

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

TABLE 1 Chemical Requirements

Copper or Copper Alloy UNS No.	Composition, %												
	Copper[A]	Tin	Aluminum	Nickel, incl Cobalt	Lead, max	Iron	Zinc	Manganese	Arsenic	Antimony	Phosphorus	Chromium	Other Named Elements
C10100	99.99 min[B]	...	...	...	0.0010	...	0.0001 max	...	...	...	0.0003 max	...	[C]
C10200[D]	99.95 min	...	...	...	...	...	...	...	...	...	...	...	...
C10300	99.95 min[E]	...	...	...	...	...	...	...	...	...	0.001–0.005	...	...
C10800	99.95 min[E]	...	...	...	...	...	...	...	...	...	0.005–0.012	...	...
C12000	99.90 min	...	...	...	...	...	...	...	...	...	0.004–0.012	...	...
C12200	99.9 min	...	...	...	...	...	...	...	...	...	0.015–0.040	...	...
C14200	99.40 min	...	...	...	...	...	...	...	0.15–0.50	...	0.015–0.040	...	...
C19200	98.7 min	...	...	...	...	0.8–1.2	...	...	...	...	0.01–0.04	...	...
C23000	84.0–86.0	...	...	...	0.05	0.05 max	remainder	...	...	...	...	...	...
C28000	59.0–63.0	...	...	...	0.30	0.07 max	remainder	...	...	...	...	...	...
C44300	70.0–73.0	0.9–1.2	...	...	0.07	0.06 max	remainder	...	0.02–0.06	...	...	...	...
C44400	70.0–73.0	0.9–1.2	...	...	0.07	0.06 max	remainder	...	...	0.02–0.10	...	...	...
C44500	70.0–73.0	0.9–1.2	...	...	0.07	0.06 max	remainder	...	...	...	0.02–0.10	...	...
C60800	remainder	...	5.0–6.5	...	0.10	0.10 max	...	...	0.02–0.35	...	...	...	...
C61300	remainder	0.20–0.50	6.0–7.5	0.15 max	0.01	2.0–3.0	0.10 max	0.20 max	...	...	0.015 max	...	[F,G]
C61400	remainder	...	6.0–8.0	...	0.01	1.5–3.5	0.20 max	1.0 max	...	...	...	...	...
C68700	76.0–79.0	...	1.8–2.5	...	0.07	0.06 max	remainder	...	0.02–0.10	...	...	...	...
C70400	remainder	...	...	4.8–6.2	0.05	1.3–1.7	1.0 max	0.30–0.8	...	...	...	...	...
C70600	remainder	...	...	9.0–11.0	0.05[H]	1.0–1.8	1.0 max[H]	1.0 max	...	...	[H]	...	[H]
C71000	remainder	...	...	19.0–23.0	0.05[H]	0.50–1.0	1.0 max[H]	1.0 max	...	...	[H]	...	[H]
C71500	remainder	...	...	29.0–33.0	0.05[H]	0.40–1.0	1.0 max[H]	1.0 max	...	...	[H]	...	[H]
C71640	remainder	...	...	29.0–32.0	0.05[H]	1.7–2.3	1.0 max[H]	1.5–2.5	...	...	[H]	...	[H]
C72200	remainder	...	...	15.0–18.0	0.05[H]	0.50–1.0	1.0 max[H]	1.0 max	...	...	[H]	0.30–0.70	[H]

[A] Copper (including silver).

[B] This value is exclusive of silver and shall be determined by difference of "impurity total" from 100 %. "Impurity total" is defined as the sum of sulfur, silver, lead, tin, bismuth, arsenic, antimony, iron, nickel, mercury, zinc, phosphorus, selenium, tellurium, manganese, cadmium, and oxygen present in the sample.

[C] Impurity maximums in ppm for C10100 shall be: antimony 4, arsenic 5, bismuth 1, cadmium 1, iron 10, lead 5, manganese 0.5, mercury 1, nickel 10, oxygen 5, phosphorus 3, selenium 3, silver 25, sulfur 15, tellurium 2, tin 2, and zinc 1.

[D] Oxygen in C10200 shall be 10 ppm max.

[E] Copper plus sum of named elements shall be 99.95 % min

[F] Silicon shall be 0.10 % max.

[G] When the product is for subsequent welding applications and is so specified by the purchaser, chromium shall be 0.05 % max, cadmium 0.05 % max, zinc 0.05 % max, and zirconium 0.05 % max.

[H] When the product is for subsequent welding applications, and so specified by the purchaser, zinc shall be 0.50 % max, lead 0.02 % max, phosphorus 0.02 % max, sulfur 0.02 % max, and carbon 0.05 % max.

3.1.1 *lengths*—straight pieces of the product.

3.1.1.1 *specific*—straight lengths that are uniform in length, as specified, and subject to established length tolerances.

3.1.2 *tube, seamless*—a tube produced with a continuous periphery in all stages of the operations.

3.1.2.1 *tube, condenser*—See *tube, heat exchanger.*

3.1.2.2 *tube, ferrule*—a tube from which metal rings or collars (ferrules) are made for use in installing condenser tubes.

3.1.2.3 *tube, heat exchanger*—a tube manufactured to special requirements as to dimensional tolerances, finish, and temper for use in condensers and other heat exchangers.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *capable of*—the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity of each size (number of pieces and number of feet),

4.1.2 Material (Section 1),

4.1.3 Form (tube or ferrule stock),

4.1.4 Temper (Section 7),

4.1.5 Whether tension test is required (Section 7),

4.1.6 Whether a pressure test is to be used instead of the eddy current test (see 13.1),

4.1.7 Dimensions, the diameter, wall thickness, whether minimum or nominal wall, and length (see Section 14),

4.1.8 Whether cut ends of the tube are to be deburred (see 15.1),

4.1.9 If the product is to be subsequently welded (see Table 1 and Footnote E).

4.1.10 Specification number and year of issue,

4.1.11 Certification, if required (see 22.1), and

4.1.12 Mill test report, if required (see 24.1).

4.2 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 herein.

5. Materials and Manufacture

5.1 The material shall be of such quality and purity that the finished product shall have the properties and characteristics prescribed in this specification, and shall be cold worked to the specified size.

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 pres-

TABLE 2 Tensile Requirements

Copper or Copper Alloy UNS No.	Temper Designation		Tensile Strength, min ksi[A]	Yield Strength,[B] min ksi[A]	Elongation in 2 in., min %
	Standard	Former			
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H55	light-drawn	36	30	...
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H80	hard-drawn	45	40	...
C19200	H55	light-drawn	40	35	...
C19200	H80	hard-drawn	48	43	...
C19200	O61	annealed	38	12	...
C23000	O61	annealed	40	12	...
C28000	O61	annealed	50	20	...
C44300, C44400, C44500	O61	annealed	45	15	...
C60800	O61	annealed	50	19	...
C61300, C61400	O61	annealed	70	30	...
C68700	O61	annealed	50	18	...
C70400	O61	annealed	38	12	...
C70400	H55	light-drawn	40	30	...
C70600	O61	annealed	40	15	...
C70600	H55	light-drawn	45	35	...
C71000	O61	annealed	45	18	...
C71500	O61	annealed	52	18	...
C71500:					
Wall thicknesses up to 0.048 in., incl	HR50	drawn, stress-relieved	72	50	12
Wall thicknesses over 0.048 in.	HR50	drawn, stress-relieved	72	50	15
C71640	O61	annealed	63	25	...
C71640	HR50	drawn, stress relieved	81	58	...
C72200	O61	annealed	45	16	...
C72200	H55	light-drawn	50	30	...

[A] ksi = 1000 psi.
[B] At 0.5 % extension under load.

ence of other elements. Limits for unnamed elements may be established by agreement between manufacturer or supplier and purchaser.

6.2.1 *Copper Alloy UNS No. C19200*—Copper may be taken as the difference between the sum of all the elements analyzed and 100 %. When all the elements in Table 1 are analyzed, their sum shall be 99.8 % minimum.

6.2.2 For copper alloys in which copper is specified as the remainder, copper may be taken as the difference between the sum of all the elements analyzed and 100 %.

6.2.2.1 When all the elements in Table 1 are analyzed, their sum shall be as shown in the following table.

Copper Alloy UNS No.	Copper Plus Named Elements, % min.
C60800	99.5
C61300	99.8
C61400	99.5
C70400	99.5
C70600	99.5
C71000	99.5
C71500	99.5
C71640	99.5
C72200	99.8

6.2.3 For copper alloys in which zinc is specified as the remainder, either copper or zinc may be taken as the difference between the sum of all the elements analyzed and 100 %.

6.2.3.1 When all the elements in Table 1 are analyzed, their sum shall be as shown in the following table.

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C23000	99.8
C28000	99.7
C44300	99.6
C44400	99.6
C44500	99.6
C68700	99.5

7. Temper

7.1 Tubes of Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, C68700, and C71000 shall be furnished in the annealed (O) temper unless otherwise specified on the purchase order.

7.2 Tubes of Copper Alloy UNS Nos. C71500 and C71640 shall be supplied in one of the following tempers as specified: (*1*) annealed (O) or (*2*) drawn, stress-relieved (HR50).

7.3 Tubes of Copper Alloy UNS Nos. C10100, C10200, C10300, C10800, C12000, C12200, and C14200 shall be supplied in any one of the following tempers, one of which shall be specified: (*1*) light-drawn (H55), (*2*) hard-drawn (H80), or (*3*) hard-drawn, end-annealed.

7.4 Tubes of Copper Alloy UNS No. C19200 shall be supplied in any one of the following tempers, one of which shall be specified: (*1*) annealed (O), (*2*) light-drawn (H55), (*3*) hard-drawn (H80), or (*4*) hard-drawn, end-annealed.

7.5 Tubes of Copper Alloy UNS Nos. C70400, C70600, and C72200 may be supplied in either light-drawn (H55) or annealed (O) temper.

7.6 Tubes for ferrule stock shall be annealed sufficiently to be fully recrystallized.

NOTE 2—Some tubes, when subjected to aggressive environments, may be subjected to stress-corrosion cracking failure because of the residual tensile stresses developed in straightening. For such applications, it is suggested that tubes of Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, and C68700 be subjected to a stress-relieving thermal treatment subsequent to straightening. If required, this must be specified on the purchase order or contract. Tolerances for roundness and length, and the condition of straightness, for tube so ordered, shall be to the requirements agreed upon between the manufacturer and the purchaser.

TABLE 3 Expansion Requirements

Temper Designation		Copper or Copper Alloy UNS No.	Expansion of Tube Outside Diameter, in Percent of Original Outside Diameter
Standard	Former		
O61	annealed	C19200	30
		C23000	20
		C28000	15
		C44300, C44400, C44500	20
		C60800	20
		C61300, C61400	20
		C68700	20
		C70400	30
		C70600	30
		C71000	30
		C71500	30
		C71640	30
		C72200	30
H55	light-drawn	C10100, C10200, C10300, C10800, C12000, C12200	20
		C14200	20
		C19200	20
		C70400	20
		C70600	20
		C72200	20
HR50	drawn, stress relieved	C71500	20
		C71640	20
...	hard-drawn, end annealed	C10100, C10200, C10300, C10800, C12000, C12200, C14200	30

8. Mechanical Properties

8.1 Material specified to meet the requirements of the *ASME Boiler and Pressure Vessel Code* shall have tensile properties as prescribed in Table 2.

9. Microscopical Examination

9.1 Samples of annealed-temper tubes selected for test shall be subjected to microscopical examination at a magnification of 75 diameters and shall show uniform and complete recrystallization. Materials other than Copper Alloy UNS Nos. C19200 and C28000 shall have an average grain size within the limits of 0.010 to 0.045 mm. These requirements do not apply to tubes of light-drawn (H55), hard-drawn (H80), hard-drawn, end-annealed, or drawn, stress-relieved tempers (HR50).

10. Expansion Test

10.1 Tube specimens selected for test shall withstand the expansion shown in Table 3 when expanded in accordance with Test Method B 153. The expanded tube shall show no cracking or rupture visible to the unaided eye.

NOTE 3—The term "unaided eye" as used herein permits the use of corrective spectacles necessary to obtain normal vision.

10.2 Hard-drawn tubes not end-annealed are not subject to this test. When tubes are specified end-annealed, this test is required and shall be made on the annealed ends.

10.3 Tubes for ferrule stock are not subject to the expansion test.

11. Flattening Test

11.1 Test specimens at least 18 in. in length in the annealed condition shall be flattened on different elements throughout the lengths remaining after specimens for the expansion and metallographic tests have been taken. Each element shall be slowly flattened by one stroke of a press. The term "flattened" shall be interpreted as follows: a micrometer caliper set at three times the wall thickness shall pass over the tube freely throughout the flattened part except at the points where the change in element of flattening takes place. The flattened elements shall not show cracking or rupture clearly visible to the unaided eye (Note 3). When tubes are specified in a temper other than annealed this test is required but shall be made on annealed specimens.

11.2 Tubes for ferrule stock are not subject to flattening test.

12. Mercurous Nitrate Test

12.1 **Warning**—Mercury is a definite health hazard and therefore equipment for the detection and removal of mercury vapor produced in volatilization is recommended.

TABLE 4 Notch Depth

Tube Wall Thickness, in.	Tube Outside Diameter, in.		
	Over 1/4 to 3/4, incl	Over 3/4 to 1 1/4, incl	Over 1 1/4 to 3 1/8, incl
Over 0.017–0.032	0.005	0.006	0.007
Incl 0.032–0.049	0.006	0.006	0.0075
Incl 0.049–0.083	0.007	0.0075	0.008
Incl 0.083–0.109	0.0075	0.0085	0.0095
Incl 0.109–0.120	0.009	0.009	0.011

TABLE 5 Diameter of Drilled Holes

Tube Outside Diameter, in.	Diameter of Drilled Holes, in.	Drill No.
1/4–3/4, incl	0.025	72
Over 3/4–1, incl	0.031	68
Over 1–1 1/4, incl	0.036	64
Over 1 1/4–1 1/2, incl	0.042	58
Over 1 1/2–1 3/4, incl	0.046	56
Over 1 3/4–2, incl	0.052	55

The use of rubber gloves in testing is advisable.

12.2 The test specimens, cut 6 in. in length, shall withstand without cracking, an immersion in the standard mercurous nitrate solution prescribed in Test Method B 154. The test specimen shall include the finished tube end. The mercurous nitrate test is required only for Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, and C68700.

13. Nondestructive Testing

13.1 Each tube shall be subjected to the eddy-current test in 13.1.1. Tubes may be tested in the final drawn, annealed, or heat-treated temper or in the drawn temper prior to the final anneal or heat treatment unless otherwise agreed upon by the supplier and the purchaser. The purchaser may specify either of the tests in 13.1.2 or 13.1.3 as an alternative to the eddy-current test.

13.1.1 *Eddy-Current Test*—Each tube shall be passed through an eddy-current testing unit adjusted to provide information on the suitability of the tube for the intended application. Testing shall follow the procedures of Practice E 243.

13.1.1.1 The depth of the round-bottom transverse notches and the diameters of the drilled holes in the calibrating tube used to adjust the sensitivity of the test unit are shown in Tables 4 and 5, respectively.

13.1.1.2 Tubes that do not actuate the signaling device of the eddy-current tester shall be considered to conform to the requirements of this test. Tubes causing irrelevant signals because of moisture, soil, and like effects may be reconditioned and retested. Such tubes, when retested to the original test parameters, shall be considered to conform if they do not cause output signals beyond the acceptable limits. Tubes causing irrelevant signals because of visible and identifiable handling marks may be retested by the hydrostatic test prescribed in 13.1.2, or the pneumatic test prescribed in 13.1.3. Tubes meeting requirements of either test shall be considered to conform if the tube dimensions are within the prescribed limits, unless otherwise agreed upon between the manufacturer and the purchaser.

13.1.2 *Hydrostatic Test*—Each tube shall stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 7000 psi, determined by the following equation for thin hollow cylinders under tension. The tube need not be tested at a hydrostatic pressure of over 1000 psi unless so specified.

$$P = 2St/(D - 0.8t)$$

where:

P = hydrostatic pressure, psig,
t = thickness of tube wall, in.,
D = outside diameter of the tube, in., and
S = allowable stress of the material, psi.

13.1.3 *Pneumatic Test*—Each tube shall be subjected to an internal air pressure of 60 psig, min, for 5 s without showing evidence of leakage. The test method used shall permit easy visual detection of any leakage, such as by having the tube under water or by the pressure differential method. Any evidence of leakage shall be cause for rejection.

14. Dimensions and Permissible Variations

14.1 *Diameter*—The outside of the tubes shall not vary from that specified by more than the amounts shown in Table 6 as measured by "go" and "no-go" ring gages.

14.2 *Wall Thickness Tolerances:*

14.2.1 *Tubes Ordered to Minimum Wall*—No tube wall at its thinnest point shall be less than the specified wall thickness. The maximum plus deviation from the specified wall at any point shall not exceed twice the values shown in Table 7.

14.2.2 *Tubes Ordered to Nominal Wall*—The maximum plus and minus deviation from the nominal wall at any point shall not exceed the values shown in Table 7.

14.3 *Length*—The length of the tubes shall not be less than that specified when measured at a temperature of 20°C, but may exceed the specified value by the amounts given in Table 8.

14.4 *Squareness of Cut*—The departure from squareness of the end of the tube shall not exceed the following:

Tube, Outside Diameter, in.	Tolerance
Up to ⅝, incl	0.010 in.
Over ⅝	0.016 in./in. of diameter

14.5 For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the specified limiting values for any dimensions may be cause for rejection.

15. Workmanship, Finish, and Appearance

15.1 Roundness, straightness, uniformity of the wall thickness, and inner and outer surface of the tube shall be such as to make it suitable for the intended application. Unless otherwise specified on the purchase order, the cut

TABLE 6 Diameter Tolerances

Outside Diameter, in.	Wall Thickness, in.				
	0.020[A] 0.022 0.025 0.028	0.032	0.035	0.042	0.049 and Over
	Diameter Tolerance, Plus and Minus, in.				
Up to 0.500, incl	0.003	0.0025	0.0025	0.0025	0.0025
Over 0.500–0.740, incl	0.0040	0.004	0.004	0.0035	0.003
Over 0.740–1.000, incl	0.0060	0.006	0.005	0.0045	0.004
Over 1.000–1.250, incl	...	0.009	0.008	0.006	0.0045
Over 1.250–1.375, incl	...	...	...	0.008	0.005
Over 1.375–2.000, incl	...	...	...	...	0.006

[A] Tolerances in this column are applicable to light drawn and drawn tempers only. Tolerances for annealed tempers shall be as agreed upon between the manufacturer and the purchaser.

TABLE 7 Wall Thickness Tolerances, Plus and Minus in.

Wall Thickness, in.	Outside Diameter, in.		
	Over 1/8 to 5/8, incl	Over 5/8 to 1, incl	Over 1 to 2, incl
0.020, incl to 0.032	0.003	0.003	...
0.032, incl to 0.035	0.003	0.003	0.004
0.035, incl to 0.058	0.004	0.0045	0.0045
0.058, incl to 0.083	0.0045	0.005	0.005
0.083, incl to 0.120	0.005	0.0065	0.0065
0.120, incl to 0.134	0.007	0.007	0.0075

ends of the tubes shall be deburred by use of a rotating wire wheel or other suitable tool.

15.2 Annealed-temper or stress-relieved tubes shall be clean and smooth but may have a superficial, dull iridescent film on both the inside and the outside surface. Drawn-temper tubes shall be clean and smooth, but may have a superficial film of drawing lubricant on the surfaces.

16. Sampling

16.1 *Sampling*—The lot size, portion size, and selection of sample pieces shall be as follows:

16.1.1 *Lot Size*—600 tubes or 10 000 lb or fraction of either, whichever constitutes the greater weight.

16.1.2 *Portion Size*—Sample pieces from two individual lengths of finished product.

16.2 Samples taken for the purpose of the tests prescribed in the specification shall be selected in a manner that will represent correctly the material furnished and avoid needless destruction of finished material when samples representative of the material are available from other sources.

17. Number of Tests and Retests

17.1 *Chemical Analysis*—Samples for chemical analysis shall be taken in accordance with Practice E 55. Drillings, millings, etc., shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 16.1.2 and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

17.1.1 Instead of sampling in accordance with Practice E 55, the manufacturer shall have the option of determining conformance to chemical composition as follows: Conformance shall be determined by the manufacturer by analyzing samples taken at the time the castings are poured or samples taken from the semi-finished product. If the manufacturer determines the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product. The number of samples taken for determination of chemical composition shall be as follows:

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

17.1.1.2 When samples are taken from the semi-finished product, a sample shall be taken to represent each 10 000 lb or fraction thereof, except that not more than one sample shall be required per piece.

17.1.1.3 Due to the discontinuous nature of the processing of castings into wrought products, it is not practical to identify specific casting analysis with a specific quantity of finished material.

17.1.1.4 In the event that heat identification or traceability is required, the purchaser shall specify the details desired.

17.2 *Other Tests*—For tests specified in Sections 8 to 12 inclusive, specimens shall be taken from each of the pieces selected in accordance with 16.1.2.

17.3 If any test specimen representing a lot fails to conform to the requirements of Sections 6, 7, 8, 9, 10, 11, and 12, two additional specimens, at the option of the manufacturer, may be taken as before, and submitted for check analysis or subjected to any tests in which the original specimen failed, but each of these specimens shall conform to the requirements specified.

TABLE 8 Length Tolerances

Specified Length, ft	Tolerance, all Plus, in.
Up to 15	3/32
Over 15–20, incl	1/8
Over 20–30, incl	5/32
Over 30–60, incl	3/8
Over 60–100, incl[A]	1/2

[A] Condenser tubes in lengths over 100 ft are not in present demand. Tolerance values for the lengths will be developed as experience dictates. Tolerance values for lengths in wall thicknesses of 0.020, incl. to 0.032 shall be as agreed upon between the manufacturer or supplier and the purchaser.

18. Test Methods

18.1 The properties and chemical compositions enumerated in this specification shall, in case of disagreement, be determined in accordance with the following ASTM methods:

Test	ASTM Designation
Chemical analysis	B 170,[A] E 53, E 54, E 62, E 75, E 478
Grain size	E 112
Expansion (pin test)	B 153
Mercurous nitrate	B 154
Tension	E 8
Nondestructive test	E 243

[A] Reference to Specification B 170 is to the suggested chemical methods in the annex thereof. When E-1 Committee has tested and published methods for assaying the low-level impurities in copper, the Specification B 170 annex will be eliminated.

18.2 The surface of the test specimen for microscopical examination shall approximate a radial longitudinal section of the tube.

18.3 Tubes selected for test shall be subjected to the tension test which shall, in case of disagreement, be made in accordance with Test Methods E 8. Tension test specimen shall be of the full section of the tube and shall conform to the requirements of the section, Specimens for Pipe and Tube, of Test Methods E 8, unless the limitations of the testing machine preclude the use of such a specimen. Test specimens conforming to Type No. 1 of Fig. 13, Tension Test Specimens for Large-Diameter Tubular Products, of Test Methods E 8, may be used when a full section specimen cannot be tested.

18.4 Whenever tension test results are obtained from both full size and from machined specimens and they differ, the results obtained from full-size test specimens shall be used to

determine conformance to the specification requirements.

18.5 Tension test results on material covered by this specification are not seriously affected by variations in speed of testing. A considerable range of testing speed is permissible; however, the range of stressing to the yield strength should not exceed 100 ksi/min. Above the yield strength the movement per minute of the testing machine head under load should not exceed 0.5 in./in. of gage length (or distance between grips for full-section specimens).

19. Significance of Numerical Limits

19.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Practice E 29:

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	nearest unit in the last right-hand place of figures
Tensile strength, Yield strength	nearest ksi, for over 10 to 100 ksi, incl
Elongation	nearest 1 %
Grain size	nearest multiple of 0.005 mm

20. Inspection

20.1 The manufacturer shall inspect and make necessary tests to verify that the tubes furnished conform to the requirements of this specification.

20.2 If in addition the purchaser elects to perform his own inspection, the manufacturer shall afford the inspector all reasonable facilities to satisfy him that the tubes are being furnished in accordance with this specification. All tests (except check analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere with the operation of the works. When automated finishing and inspection equipment is available at a facility, purchaser and supplier may by mutual agreement accomplish the final inspection simultaneously.

21. Rejection and Rehearing

21.1 Material that fails to conform to the requirements of this specification when inspected or tested by the purchaser or his agent may be rejected. Rejection should be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer or supplier may make claim for a rehearing.

22. Certification

22.1 When specified on the purchase order the manufacturer shall furnish to the purchaser a certificate stating that each lot has been sampled, tested, and inspected in accordance with this specification and has met the requirements. When material is specified to meet the requirements of *ASME Boiler and Pressure Vessel Code*, the certification requirements are mandatory.

23. Packaging and Package Marking

23.1 The material shall be separated by size, composition, and temper, and prepared for shipment in such a manner as to ensure acceptance by common carrier for transportation and to afford protection from the normal hazards of transportation.

23.2 Each shipping unit shall be legibly marked with the purchase order number, metal or alloy designation, temper, size, shape, total length or piece count, or both, and name of supplier. The specification number shall be shown, when specified.

24. Mill Test Report

24.1 When specified on the purchase order, the manufacturer shall furnish to the purchaser a test report showing results of tests required by the specification.

25. Keywords

25.1 condenser tube; copper; copper alloys; evaporator; ferrule stock; heat exchanger; seamless tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U. S. Government.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

S1.1.1 *Federal Standards:*[10]

Fed. Std. No. 102 Preservation, Packaging and Packing Levels

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 185 Identification Marking of Copper and Copper-Base Alloy Mill Products

S1.1.2 *Military Standard:*[10]

MIL-STD-129 Marking for Shipment and Storage

S1.1.3 *Military Specification:*[10]

MIL-C-3993 Packaging of Copper and Copper-Base Alloy Mill Products

S2. Quality Assurance

S2.1 *Responsibility for Inspection:*

S2.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to assure that the material

[10] Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

conforms to prescribed requirements.

S3. Identification Marking

S3.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 185 except that the ASTM specification number and the alloy number shall be used.

S4. Preparation for Delivery

S4.1 *Preservation, Packaging, Packing:*

S4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade or class and shall be preserved and packaged, Level A or C, packed Level A, B, or C as specified in the contract or purchase order, in accordance with the requirements of MIL-C-3993.

S4.1.2 *Civil Agencies*—The requirements of Fed. Std. No.102 shall be referenced for definitions of the various levels of packaging protection.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

APPENDIX

(Nonmandatory Information)

X1. DENSITY OF COPPER AND COPPER ALLOYS

X1.1 The densities of the alloys covered by this specification are given in Table X1.1.

TABLE X1.1. Densities

Copper or Copper Alloy UNS No.	Density, lb/in.^{3}
C10100, C10200, C10300, C10800, C12000, C12200, C14200	0.323
C19200	0.320
C23000	0.316
C28000	0.303
C44300, C44400, C44500	0.308
C60800	0.295
C61300, C61400	0.285
C68700	0.301
C70400	0.323
C70600	0.323
C71000	0.323
C71500	0.323
C71640	0.323
C72200	0.323

Designation: B 111M – 93
METRIC

Standard Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock [Metric][1]

This standard is issued under the fixed designation B 111M; 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. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification[2] covers seamless tube and ferrule stock of copper and various copper alloys up to 79 mm, inclusive, in diameter, for use in surface condensers, evaporators, and heat exchangers. Tubes for this application are normally made from the following coppers or copper alloys:

Copper or Copper Alloy UNS No.[3]	Previously Used Designation	Type of Metal
C10100	OFE	Oxygen-free electronic
C10200	OF[A]	Oxygen-free without residual deoxidants
C10300	...	Oxygen-free, extra low phosphorus
C10800	...	Oxygen-free, low phosphorus
C12000	DLP[A]	Phosphorized, low residual phosphorus
C12200	DHP[A]	Phosphorized, high residual phosphorus
C14200	DPA[A]	Phosphorized, arsenical
C19200	...	Phosphorized, 1 % iron
C23000	...	Red Brass
C28000	...	Muntz Metal
C44300	...	Admiralty Metals, B, C, and D
C44400		
C44500		
C60800	...	Aluminum Bronze
C61300	...	
C61400	...	Aluminum Bronze, D
C68700	...	Aluminum Brass, B
C70400	...	95-5 Copper-Nickel
C70600	...	90-10 Copper-Nickel
C71000	...	80-20 Copper-Nickel
C71500	...	70-30 Copper-Nickel
C71640	...	Copper-nickel-iron-manganese
C72200	...	...

[A] Designations listed in Classification B 224.

NOTE 1—This specification is the metric companion to Specification B 111.

NOTE 2—**Warning:** Mercury is a definite health hazard in use and disposal. (See 12.1.)

1.2 The following safety hazards caveat pertains only to the test methods portion, Section 18, of this specification: *This standard does not purport to address all of the safety problems, 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:

2.1.1 *ASTM Standards:*

B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing[4]
B 154 Method for Mercurous Nitrate Test for Copper and Copper Alloys[4]
B 170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes[4]
B 224 Classification of Coppers[4]
E 8 Test Methods for Tension Testing of Metallic Materials[5]
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[6]
E 53 Methods for Chemical Analysis of Copper[7]
E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes[7]
E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[7]
E 62 Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)[7]
E 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys[7]
E 112 Test Methods for Determining Average Grain Size[5]
E 243 Practice for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes[8]
E 478 Test Methods for Chemical Analysis of Copper Alloys[7]
E 527 Practice for Numbering Metals and Alloys (UNS)[9]

3. Terminology

3.1 *Definitions:*

3.1.1 *lengths*—straight pieces of the product.

3.1.1.1 *specific*—straight lengths that are uniform in

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.04 on Pipe and Tube.

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[2] For *ASME Boiler and Pressure Vessel Code* applications see related Specification SB-111 in Section 11 of the code.

[3] 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.

[4] *Annual Book of ASTM Standards*, Vol 02.01.
[5] *Annual Book of ASTM Standards*, Vol 03.01.
[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 03.03.
[9] *Annual Book of ASTM Standards*, Vol 01.01.

collars (ferrules) are made for use in installing condenser tubes.

3.1.2 *lengths*—straight pieces of the product.

3.1.2.1 *specific*—straight lengths that are uniform in length, as specified, and subject to established length tolerances.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *capable of*—the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Quantity of each size (number of pieces and number of metres),

4.1.2 Material (Section 1),

4.1.3 Form (tube or ferrule stock),

4.1.4 Temper (Section 7),

4.1.5 Whether tension test is required (Section 7),

4.1.6 Whether a pressure test is to be used instead of the eddy-current test (see 13.1),

4.1.7 Dimensions, the diameter, wall thickness, whether minimum or nominal wall, and length (see Section 14),

4.1.8 Whether cut ends of the tube are to be deburred (see 15.1),

4.1.9 If the product is to be subsequently welded (see Table 1 and Footnote H),

4.1.10 Specification number and year of issue,

4.1.11 Certification, if required (see 22.1), and

4.1.12 Mill test report, if required (see 24.1).

4.2 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 herein.

5. Materials and Manufacture

5.1 The material shall be of such quality and purity that the finished product shall have the properties and characteristics prescribed in this specification, and shall be cold worked to the specified size.

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.

6.2.1 *Copper Alloy UNS No. C19200*—Copper may be taken as the difference between the sum of all the elements

TABLE 1 Chemical Requirements

Copper or Copper Alloy UNS No.	Composition, %												
	Copper[A]	Tin	Aluminum	Nickel, incl Cobalt	Lead, max	Iron	Zinc	Manganese	Arsenic	Antimony	Phosphorus	Chromium	Other Named Elements
C10100	99.99 min[B]	...	...	...	0.0010	...	0.0001 max	...	...	...	0.0003 max	...	[C]
C10200[D]	99.95 min	...	...	...	...	...	...	...	...	...	...	...	...
C10300	99.95 min[E]	...	...	...	...	...	...	...	...	...	0.001–0.005	...	...
C10800	99.95 min[E]	...	...	...	...	...	...	...	...	...	0.005–0.012	...	...
C12000	99.90 min	...	...	...	...	...	...	...	...	...	0.004–0.012	...	...
C12200	99.9 min	...	...	...	...	...	...	...	...	...	0.015–0.040	...	...
C14200	99.40 min	...	...	...	...	...	...	...	0.15–0.50	...	0.015–0.040	...	...
C19200	98.7 min	...	...	...	...	0.8–1.2	...	...	...	...	0.01–0.04	...	...
C23000	84.0–86.0	...	...	...	0.05	0.05 max	remainder	...	...	...	...	...	...
C28000	59.0–63.0	...	...	...	0.30	0.07 max	remainder	...	...	...	...	...	...
C44300	70.0–73.0	0.9–1.2	...	...	0.07	0.06 max	remainder	...	0.02–0.06	...	...	...	...
C44400	70.0–73.0	0.9–1.2	...	...	0.07	0.06 max	remainder	...	...	0.02–0.10	...	...	...
C44500	70.0–73.0	0.9–1.2	...	...	0.07	0.06 max	remainder	...	...	...	0.02–0.10	...	...
C60800	remainder	...	5.0–6.5	...	0.10	0.10 max	...	...	0.02–0.35	...	...	...	...
C61300	remainder	0.20–0.50	6.0–7.5	0.15 max	0.01	2.0–3.0	0.10 max	0.20 max	...	...	0.015 max	...	[F,G]
C61400	remainder	...	6.0–8.0	...	0.01	1.5–3.5	0.20 max	1.0 max	...	...	...	...	...
C68700	76.0–79.0	...	1.8–2.5	...	0.07	0.06 max	remainder	...	0.02–0.10	...	...	...	...
C70400	remainder	...	...	4.8–6.2	0.05	1.3–1.7	1.0 max	0.30–0.8	...	...	...	...	...
C70600	remainder	...	...	9.0–11.0	0.05[H]	1.0–1.8	1.0 max[H]	1.0 max	...	...	...	...	[H]
C71000	remainder	...	...	19.0–23.0	0.05[H]	0.50–1.0	1.0 max[H]	1.0 max	...	...	...	...	[H]
C71500	remainder	...	...	29.0–33.0	0.05[H]	0.40–1.0	1.0 max[H]	1.0 max	...	...	...	...	[H]
C71640	remainder	...	...	29.0–32.0	0.05[H]	1.7–2.3	1.0 max[H]	1.5–2.5	...	...	...	...	[H]
C72200	remainder	...	...	15.0–18.0	0.05[H]	0.50–1.0	1.0 max[H]	1.0 max	...	...		0.30–0.70	[H]

[A] Copper (including silver).

[B] This value is exclusive of silver and shall be determined by difference of "impurity total" from 100 %. "Impurity total" is defined as the sum of silver, lead, tin, bismuth, arsenic, antimony, iron, nickel, mercury, zinc, phosphorus, selenium, tellurium, manganese, cadmium, and oxygen present in the sample.

[C] Impurity maximums in ppm for C101000 shall be: antimony 4, arsenic 5, bismuth 1, cadmium 1, iron 10, lead 5, manganese 0.5, mercury 1, nickel 10, oxygen 5, phosphorus 3, selenium 3, silver 25, sulfur 15, tellurium 2, tin 2, and zinc 1.

[D] Oxygen in C10200 shall be 10 ppm max.

[E] Copper plus sum of named elements shall be 99.95 % min.

[F] Silicon shall be 0.10 % max.

[G] When the product is for subsequent welding applications and is so specified by the purchaser, chromium shall be 0.05 % max, cadmium 0.05 % max, zinc 0.05 % max, and zirconium 0.05 % max.

[H] When the product is for subsequent welding applications, and so specified by the purchaser, zinc shall be 0.50 % max, lead 0.02 % max, phosphorus 0.02 % max, sulfur 0.02 % max, and carbon 0.05 % max.

analyzed and 100 %. When all the elements in Table 1 are analyzed, their sum shall be 99.8 % minimum.

6.2.2 For copper alloys in which copper is specified as the remainder, copper may be taken as the difference between the sum of all the elements analyzed and 100 %.

6.2.2.1 When all the elements in Table 1 are analyzed, their sum shall be as shown in the following table.

Copper Alloy UNS No.	Copper Plus Named Elements, % min.
C60800	99.5
C61300	99.8
C61400	99.5
C70400	99.5
C70600	99.5
C71000	99.5
C71500	99.5
C71640	99.5
C72200	99.8

6.2.3 For copper alloys in which zinc is specified as the remainder, either copper or zinc may be taken as the difference between the sum of all the elements analyzed and 100 %.

6.2.3.1 When all the elements in Table 1 are analyzed, their sum shall be as shown in the following table.

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C23000	99.8
C28000	99.7
C44300	99.6
C44400	99.6
C44500	99.6
C68700	99.5

7. Temper

7.1 Tubes of Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, C68700, and C71000 shall be furnished in the annealed (O) temper unless otherwise specified on the purchase order.

7.2 Tubes of Copper Alloy UNS Nos. C71500 and C71640 shall be supplied in one of the following tempers as specified: (*1*) annealed (O) or (*2*) drawn, stress-relieved (HR50).

7.3 Tubes of Copper Alloy UNS Nos. C10100, C10200, C10300, C10800, C12000, C12200, and C14200 shall be supplied in any one of the following tempers, one of which shall be specified: (*1*) light-drawn (H55), (*2*) hard-drawn (H80), or (*3*) hard-drawn, end-annealed.

7.4 Tubes of Copper Alloy UNS No. C19200 shall be supplied in any one of the following tempers, one of which shall be specified: (*1*) annealed (O), (*2*) light-drawn (H55), (*3*) hard-drawn (H80), or (*4*) hard-drawn, end-annealed.

7.5 Tubes of Copper Alloy UNS Nos. C70400, C70600, and C72200 may be supplied in either light-drawn (H55) or annealed (O) temper.

7.6 Tubes for ferrule stock shall be annealed sufficiently to be fully recrystallized.

NOTE 2—Some tubes, when subjected to aggressive environments, may be subjected to stress-corrosion cracking failure because of the residual tensile stresses developed in straightening. For such applications, it is suggested that tubes of Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, and C68700 be subjected to a stress-relieving thermal treatment subsequent to straightening. If required, this must be specified on the purchase order or contract. Tolerances for roundness and length, and the condition of straightness, for tube so ordered, shall be to the requirements agreed upon between the manufacturer and the purchaser.

8. Mechanical Properties

8.1 Material specified to meet the requirements of the *ASME Boiler and Pressure Vessel Code* shall have tensile properties as prescribed in Table 2.

TABLE 2 Tensile Requirements

Copper or Copper Alloy UNS No.	Temper Designation		Tensile Strength, min	Yield Strength,[A] min	Elongation in 50 mm, min, %
	Standard	Former	MPa	MPa	
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H55	light-drawn	250	205	...
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H80	hard-drawn	310	275	...
C19200	H55	light-drawn	275	240	...
C19200	H80	hard-drawn	330	295	...
C19200	O61	annealed	260	85	...
C23000	O61	annealed	275	85	...
C28000	O61	annealed	345	140	...
C44300, C44400, C44500	O61	annealed	310	105	...
C60800	O61	annealed	345	130	...
C61300, C61400	O61	annealed	480	205	...
C68700	O61	annealed	345	125	...
C70400	O61	annealed	260	85	...
C70400	H55	light-drawn	275	205	...
C70600	O61	annealed	275	105	...
C70600	H55	light-drawn	310	240	...
C71000	O61	annealed	310	110	...
C71500	O61	annealed	360	125	...
C71500:					
Wall thicknesses up to 1.21 mm, incl	HR50	drawn, stress-relieved	495	345	12
Wall thicknesses over 1.21 mm	HR50	drawn, stress-relieved	495	345	15
C71640	O61	annealed	435	170	...
C71640	HR50	drawn, stress-relieved	560	400	...
C72200	O61	annealed	310	110	...
C72200	H55	light-drawn	345	310	...

[A] At 0.5 % extension under load.

9. Microscopical Examination

9.1 Samples of annealed-temper tubes selected for test shall be subjected to microscopical examination at a magnification of 75 diameters and shall show uniform and complete recrystallization. Materials other than Copper Alloy UNS Nos. C19200 and C28000 shall have an average grain size within the limits of 0.010 to 0.045 mm. These requirements do not apply to tubes of light-drawn (H55), hard-drawn (H80), hard-drawn, end-annealed, or drawn, stress-relieved tempers (HR50).

10. Expansion Test

10.1 Tube specimens selected for test shall withstand the expansion shown in Table 2 when expanded in accordance with Test Method B 153. The expanded tube shall show no cracking or rupture visible to the unaided eye.

NOTE 3—The term "unaided eye" as used herein permits the use of corrective spectacles necessary to obtain normal vision.

10.2 Hard-drawn tubes not end-annealed are not subject to this test. When tubes are specified end-annealed, this test is required and shall be made on the annealed ends.

10.3 Tubes for ferrule stock are not subject to the expansion test.

11. Flattening Test

11.1 Test specimens at least 450 mm in length in the annealed condition shall be flattened on different elements throughout the lengths remaining after specimens for the expansion and metallographic tests have been taken. Each element shall be slowly flattened by one stroke of a press. The term "flattened" shall be interpreted as follows: a micrometer caliper set at three times the wall thickness shall pass over the tube freely throughout the flattened part except at the points where the change in element of flattening takes place. The flattened elements shall not show cracking or rupture clearly visible to the unaided eye (Note 4). When tubes are specified in a temper other than annealed this test is required but shall be made on annealed specimens.

11.2 Tubes for ferrule stock are not subject to flattening test.

TABLE 3 Expansion Requirements

Temper Designation		Copper or Copper Alloy UNS No.	Expansion of Tube Outside Diameter, in Percent of Original Outside Diameter
Standard	Former		
O61	annealed	C19200	30
		C23000	20
		C28000	15
		C44300, C44400, C44500	20
		C60800	20
		C61300, C61400	20
		C68700	20
		C70400	30
		C70600	30
		C71000	30
		C71500	30
		C71640	30
		C72200	30
H55	light-drawn	C10100, C10200, C10300, C10800, C12000, C12200	20
		C14200	20
		C19200	20
		C70400	20
		C70600	20
		C72200	20
HR50	drawn, stress-relieved	C71500	20
		C71640	20
...	hard-drawn, end-annealed	C10100, C10200, C10300, C10800, C12000, C12200, C14200	30

12. Mercurous Nitrate Test

12.1 **Warning**—Mercury is a definite health hazard and therefore equipment for the detection and removal of mercury vapor produced in volatilization is recommended. The use of rubber gloves in testing is advisable.

12.2 The test specimens, cut 150 mm in length, shall withstand without cracking, an immersion in the standard mercurous nitrate solution prescribed in Test Method B 154. The test specimen shall include the finished tube end. The mercurous nitrate test is required only for Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, and C68700.

13. Nondestructive Testing

13.1 Each tube shall be subjected to the eddy-current test in 13.1.1. Tubes may be tested in the final drawn, annealed, or heat-treated temper or in the drawn temper prior to the final anneal or heat treatment unless otherwise agreed upon by the supplier and the purchaser. The purchaser may specify either of the tests in 13.1.2 or 13.1.3 as an alternative to the eddy-current test.

13.1.1 *Eddy-Current Test*—Each tube shall be passed through an eddy-current testing unit adjusted to provide information on the suitability of the tube for the intended application. Testing shall follow the procedures of Practice E 243.

13.1.1.1 The depth of the round-bottom transverse notches and the diameters of the drilled holes in the calibrating tube used to adjust the sensitivity of the test unit are shown in Tables 7 and 8 respectively. The notch depth

TABLE 4 Notch Depth

Tube Wall Thickness, mm	Tube Outside Diameter, mm		
	Over 6 to 19, incl	Over 19 to 32, incl	Over 32 to 79, incl
Over 0.43–0.81	0.13	0.15	0.18
Incl 0.81–1.3†	0.15	0.15	0.19
Incl 1.3–2.1	0.18	0.19	0.20
Incl 2.1–2.8	0.19	0.22	0.24
Incl 2.8–3.0	0.23	0.23	0.28

† Editorially corrected.

TABLE 5 Diameter of Drilled Holes

Tube Outside Diameter	Diameter of Drilled Holes	Drill No.
mm	mm	
6.0–19.0, incl	0.635	72
Over 19.0–25.4, incl	0.785	68
Over 25.4–31.8, incl	0.915	64
Over 31.8–38.1, incl	1.07	58
Over 38.1–44.4, incl	1.17	56
Over 44.4–50.8, incl	1.32	55

shall not vary from the prescribed by more than ±0.015 mm when measured at the center of the notch, and the diameter of the drilled hole shall not vary by more than +0.025, −0.005 mm of the hole diameter specified.

13.1.1.2 Tubes that do not actuate the signaling device of the eddy-current tester shall be considered to conform to the requirements of this test. Tubes causing irrelevant signals because of moisture, soil, and like effects may be reconditioned and retested. Such tubes, when retested to the original test parameters, shall be considered to conform if they do not cause output signals beyond the acceptable limits. Tubes causing irrelevant signals because of visible and identifiable handling marks may be retested by the hydrostatic test precribed in 13.1.2, or the pneumatic test prescribed in 13.1.3. Tubes meeting requirements of either test shall be considered to conform if the tube dimensions are within the prescribed limits, unless otherwise agreed upon between the manufacturer and the purchaser.

13.1.2 *Hydrostatic Test*—Each tube shall stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 48 MPa, determined by the following equation for thin hollow cylinders under tension. The tube need not be tested at a hydrostatic pressure of over 6.9 MPa unless so specified.

$$P = 2St/(D - 0.8t)$$

where:

P = hydrostatic pressure, MPa,
t = thickness of tube wall, mm,
D = outside diameter of the tube, mm, and
S = allowable stress of the material, MPa.

13.1.3 *Pneumatic Test*—Each tube shall be subjected to an internal air pressure of 400 kPa, min, for 5 s without showing evidence of leakage. The test method used shall permit easy visual detection of any leakage, such as by having the tube under water or by the pressure differential method. Any evidence of leakage shall be cause for rejection.

14. Dimensions and Permissible Variations

14.1 *Diameter*—The outside of the tubes shall not vary from that specified by more than the amounts shown in Table 6 as measured by "go" and "no-go" ring gages.

14.2 *Wall Thickness Tolerances:*

14.2.1 *Tubes Ordered to Minimum Wall*—No tube wall at its thinnest point shall be less than the specified wall thickness. The maximum plus deviation from the specified wall at any point shall not exceed twice the values shown in Table 7.

TABLE 6 Diameter Tolerances

Outside Diameter, mm	Wall Thickness, mm				
	0.508[A] 0.559 0.635 0.711	0.813	0.889	1.07	1.24 and Over
	Diameter Tolerance, Plus and Minus, mm				
Up to 12, incl	0.076	0.064	0.064	0.064	0.064
Over 12–18, incl	0.10	0.10	0.10	0.089	0.076
Over 18–25, incl	0.15	0.15	0.13	0.11	0.10
Over 25–35, incl	...	...	...	0.20	0.13
Over 35–50, incl	...	...	...	...	0.15

[A] Tolerances in this column are applicable to light drawn and drawn tempers only. Tolerances for annealed tempers shall be as agreed upon between the manufacturer and the purchaser.

TABLE 7 Wall Thickness Tolerances, Plus and Minus, mm

Wall Thickness, mm	Outside Diameter, mm	
	Over 12 to 25, incl	Over 25 to 50, incl
0.506, incl to 0.813†	0.076	...
0.813, incl to 0.889	0.076	0.10
0.889, incl to 1.47	0.11	0.11
1.47, incl to 2.11	0.13	0.13
2.11, incl to 3.05	0.17	0.17
3.05, incl to 3.40	0.18	0.19

† Editorially corrected.

14.2.2 *Tubes Ordered to Nominal Wall*—The maximum plus and minus deviation from the nominal wall at any point shall not exceed the values shown in Table 7.

14.3 *Length*—The length of the tubes shall not be less than that specified when measured at a temperature of 20°C, but may exceed the specified value by the amounts given in Table 8.

14.4 *Squareness of Cut*—The departure from squareness of the end of the tube shall not exceed the following:

Tube, Outside Diameter, mm	Tolerance
Up to 15.9, incl	0.25 mm
Over 15.9	0.016 mm/mm of diameter

14.5 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.

15. Workmanship, Finish, and Appearance

15.1 Roundness, straightness, uniformity of the wall thickness, and inner and outer surface of the tube shall be such as to make it suitable for the intended application. Unless otherwise specified on the purchase order, the cut ends of the tubes shall be deburred by use of a rotating wire wheel or other suitable tool.

15.2 Annealed-temper or stress-relieved tubes shall be clean and smooth but may have a superficial, dull iridescent film on both the inside and the outside surface. Drawn-temper tubes shall be clean and smooth, but may have a superficial film of drawing lubricant on the surfaces.

16. Sampling

16.1 *Sampling*—The lot size, portion size, and selection of sample pieces shall be as follows:

16.1.1 *Lot Size*—600 tubes or 4550 kg or fraction of either, whichever constitutes the greater weight.

TABLE 8 Length Tolerances

Specified Length, mm	Tolerance, all Plus, mm
Up to 4500	2.4
Over 4500–6000, incl	3.2
Over 6000–10 000, incl	4.0
Over 10 000–18 000, incl	9.5
Over 18 000–30 000, incl[A]	13

[A] Condenser tubes in lengths over 30 000 mm are not in present demand. Tolerance values for the lengths will be developed as experience dictates. Tolerance values for lengths in wall thicknesses of 0.508, inclusive to 0.813 shall be as agreed upon between the manufacturer or supplier and the purchaser.

16.1.2 *Portion Size*—Sample pieces from two individual lengths of finished product.

16.2 Samples taken for the purpose of the tests prescribed in the specification shall be selected in a manner that will represent correctly the material furnished and avoid needless destruction of finished material when samples representative of the material are available from other sources.

17. Number of Tests and Retests

17.1 *Chemical Analysis*—Samples for chemical analysis shall be taken in accordance with Practice E 55. Drillings, millings, etc., shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 16.1.2 and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

17.1.1 Instead of sampling in accordance with Practice E 55, the manufacturer shall have the option of determining conformance to chemical composition as follows: Conformance shall be determined by the manufacturer by analyzing samples taken at the time the castings are poured or samples taken from the semifinished product. If the manufacturer determines the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product. The number of samples taken for determination of chemical composition shall be as follows:

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

17.1.1.2 When samples are taken from the semi-finished product, a sample shall be taken to represent each 4550 kg or fraction thereof, except that not more than one sample shall be required per piece.

17.1.1.3 Due to the discontinuous nature of the processing of castings into wrought products, it is not practical to identify specific casting analysis with a specific quantity of finished material.

17.1.1.4 In the event that heat identification or traceability is required, the purchaser shall specify the details desired.

17.2 *Other Tests*—For tests specified in Sections 8 to 12 inclusive, specimens shall be taken from each of the pieces selected in accordance with 16.1.2.

17.3 If any test specimen representing a lot fails to conform to the requirements of Sections 6, 7, 8, 9, 10, 11, and 12, two additional specimens, at the option of the manufacturer, may be taken as before, and submitted for check analysis or subjected to any tests in which the original specimen failed, but each of these specimens shall conform to the requirements specified.

18. Test Methods

18.1 The properties and chemical compositions enumerated in this specification shall, in case of disagreement, be determined in accordance with the following ASTM methods:

Test	ASTM Designation
Chemical analysis	E 53, E 54, E 62, E 75, E 478
Grain size	E 112
Expansion (pin test)	B 153
Mercurous nitrate	B 154
Tension	E 8
Nondestructive test	E 243

18.2 The surface of the test specimen for microscopical examination shall approximate a radial longitudinal section of the tube.

18.3 Tubes selected for test shall be subjected to the tension test which shall, in case of disagreement, be made in accordance with Test Methods E 8. The tension test specimen shall be of the full section of the tube and shall conform to the requirements of the section, Specimens for Pipe and Tube, of Test Methods E 8, unless the limitations of the testing machine preclude the use of such a specimen. Test specimens conforming to Type No. 1 of Fig. 13, Tension Test Specimens for Large-Diameter Tubular Products, of Test Methods E 8 may be used when a full-section specimen cannot be tested.

18.4 Whenever tension test results are obtained from both full-size and from machined specimens and they differ, the results obtained from full-size test specimens shall be used to determine conformance to the specification requirements.

18.5 Tension test results on material covered by this specification are not seriously affected by variations in speed of testing. A considerable range of testing speed is permissible; however, the range of stressing to the yield strength should not exceed 690 MPa/min. Above the yield strength the movement per minute of the testing machine head under load should not exceed 0.5 mm/mm of gage length (or distance between grips for full-section specimens).

19. Significance of Numerical Limits

19.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Practice E 29:

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	nearest unit in the last right-hand place of figures
Tensile strength	nearest 5 MPa
Yield strength	nearest 5 MPa
Elongation	nearest 1 %
Grain size	nearest multiple of 0.005 mm

20. Inspection

20.1 The manufacturer shall inspect and make necessary tests to verify that the tubes furnished conform to the requirements of this specification.

20.2 If in addition the purchaser elects to perform his own inspection, the manufacturer shall afford the inspector all reasonable facilities to satisfy him that the tubes are being furnished in accordance with this specification. All tests (except check analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise

specified, and shall be so conducted as not to interfere with the operation of the works. When automated finishing and inspection equipment is available at a facility, purchaser and supplier may by mutual agreement accomplish the final inspection simultaneously.

21. Rejection and Rehearing

21.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer or supplier may make claim for a rehearing.

22. Certification

22.1 When specified on the purchase order the manufacturer shall furnish to the purchaser a certificate stating that each lot has been sampled, tested, and inspected in accordance with this specification and has met the requirements. When material is specified to meet the requirements of *ASME Boiler and Pressure Vessel Code*, the certification requirements are mandatory.

23. Packaging and Package Marking

23.1 The material shall be separated by size, composition, and temper, and prepared for shipment in such a manner as to ensure acceptance by common carrier for transportation and to afford protection from the normal hazards of transportation.

23.2 Each shipping unit shall be legibly marked with the purchase order number, metal or alloy designation, temper, size, shape, total length or piece count, or both, and name of supplier. The specification number shall be shown, when specified.

24. Mill Test Report

24.1 When specified on the purchase order, the manufacturer shall furnish to the purchaser a test report showing results of tests required by the specification.

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U. S. Government.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

S1.1.1 *Federal Standards:*

Fed. Std. No. 102 Preservation, Packaging and Packing Levels[10]

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[10]

Fed. Std. No. 185 Identification Marking of Copper and Copper-Base Alloy Mill Products[10]

S1.1.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[10]

S1.1.3 *Military Specification:*[10]

MIL-C-3993 Packaging of Copper and Copper-Base Alloy Mill Products[10]

S2. Quality Assurance

S2.1 *Responsibility for Inspection:*

S2.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the preformance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to prescribed requirements.

S3. Identification Marking

S3.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 185 except that the ASTM specification number and the alloy number shall be used.

S4. Preparation for Delivery

S4.1 *Preservation, Packaging, Packing:*

S4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade or class and shall be preserved and packaged, Level A or C, packed, Level A, B, or C, as specified in the contract or purchase order, in accordance with the requirements of MIL-C-3993.

S4.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

[10] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, ATTN: NPODS.

APPENDIX

(Nonmandatory Information)

X1. DENSITY OF COPPER AND COPPER ALLOYS

X1.1 The densities of the alloys covered by this specification are given in Table X1.1.

TABLE X1.1 Densities

Copper or Copper Alloy UNS No.	Density, g/cm^3
C10100, C10200, C10300, C10800, C12000, C12200, C14200	8.94
C19200	8.86
C23000	8.75
C28000	8.39
C44300, C44400, C44500	8.53
C60800	8.17
C61300, C61400	7.89
C68700	8.33
C70400	8.94
C70600	8.94
C71000	8.94
C71500	8.94
C71640	8.94
C72200	8.94

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B122: Standard Specification for Copper-Nickel-Tin Alloy, Copper-Nickel-Zinc Alloy (Nickel Silver), and Copper-Nickel Alloy Plate, Sheet, Strip and Rolled Bar

CFR Section(s): 46 CFR 119.440

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 122/B 122M – 95

Standard Specification for Copper-Nickel-Tin Alloy, Copper-Nickel-Zinc Alloy (Nickel Silver), and Copper-Nickel Alloy Plate, Sheet, Strip, and Rolled Bar[1]

This standard is issued under the fixed designation B 122/B 122M; 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 specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers copper-nickel-tin alloy, copper-nickel-zinc alloy (nickel silver), and copper-nickel alloy plate, sheet, strip, and rolled bar. The following alloys are covered:

Copper Alloy UNS No.[2]	Previously Used Designation	Nominal Composition, %				
		Copper	Nickel	Zinc	Tin	Chromium
C 70600	...	90	10	...	...	...
C 71000	6	80	20	...	...	...
C 71500	5	70	30	...	...	...
C 72200	...	85	15	...	...	0.5
C 72500	...	89	9	...	2	...
C 73500	1	72	18	10	...	...
C 74000	9	70	10	20	...	...
C 74500	3	65	10	24	...	...
C 75200	2	65	18	17	...	...
C 76200	8	59	12	29	...	...
C 77000	4	55	18	27	...	...

NOTE 1—Plates of copper-nickel alloy Copper Alloy UNS Nos. C 70600, C 71500, and C 72200 for use as tube plates in surface condensers and heat exchangers are covered by Specification B 171.

1.2 The values stated in either inch-pound units of SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used in independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.2.1 When the product is ordered in inch-pound units, the inch-pound units are to be regarded as the standard except grain size is always specified in millimeters.

1.2.2 When the product is ordered in SI units, the SI units are to be regarded as the standard.

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:

2.1.1 *ASTM Standards:*

B 171 Specification for Copper-Alloy Plate and Sheet for Pressure Vessels, Condensers, and Heat Exchangers[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]

E 527 Practice for Numbering Metals and Alloys (UNS)[4]

3. Ordering Information

3.1 Orders for material under this specification should include the following information:

3.1.1 Alloy number (Section 1),

3.1.1.1 Whether the alloy ordered will be used in applications requiring it to be welded (see Table 1, Footnote B),

3.1.2 Temper (Section 6),

3.1.3 Dimensions: thickness and width (see 10.2 and 10.3),

3.1.4 Type of edge, if required: slit, sheared, sawed, square corners, rounded corners, rounded edges, or full rounded edges (see 10.6),

3.1.5 How furnished: flat or rolls,

3.1.6 Length (see 10.4), and

3.1.7 Weight: total for each size.

3.1.8 ASTM Specification B 122/B 122M, year of issue.

3.2 In addition, when material is purchased for agencies of the U.S. Government, it shall conform to the Supplementary Requirements as defined in Specification B 248 when specified in the contract or purchase order.

4. General Requirements

4.1 Products furnished under this specification in inch-pound units shall conform to the applicable requirements of the current edition of Specification B 248.

4.2 Products furnished under this specification in SI Units shall conform to the applicable requirements of the current edition of Specification B 248M.

[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.

Current edition approved Nov. 10, 1995. Published January 1996. Originally published as B 122 – 39 T. Last previous edition B 122 – 92a.

[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.

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

5. Chemical Composition

5.1 The material shall conform to the chemical composition prescribed in Table 1.

5.2 These specification limits do not preclude the presence of other elements. Limits may be established for unnamed elements by agreement between manufacturer or supplier and purchaser.

5.2.1 For copper alloys for which copper is specified as a remainder, copper may be taken as the difference between the sum of all the elements analyzed and 100 %. When all the elements in Table 1 are analyzed, their sum shall be as follows:

Copper Alloy UNS No.	Copper plus Named Elements, % min
C70600	99.5
C71000	99.5
C71500	99.5
C72200	99.5
C72500	99.8

5.2.2 For copper alloys for which zinc is specified as a remainder, either copper or zinc 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 as follows:

Copper Alloy UNS No.	Copper plus Named Elements, % min
C73500	99.5
C74000	99.5
C74500	99.5
C75200	99.5
C76200	99.5
C77000	99.5

6. Temper

6.1 *As Hot-Rolled (M20) Material*—The standard temper of sheet and plate produced by hot rolling and is as designated in Table 2.

6.2 *Rolled (H) Material*—The standard tempers of rolled material are as designated in Table 2 with the prefix "H". Former designations and the standard designations as defined in Practice B 601 are shown. Special or nonstandard tempers are subject to negotiation between manufacturer and purchaser (See 3.1.2).

6.3 *Annealed*—The standard temper is O60 (soft), as indicated in Table 2.

7. Mechanical Properties of Rolled Tempers

7.1 *Tensile Strength:*

7.1.1 Products ordered to this specification in inch-pound units shall conform to the tensile strength requirements prescribed in ksi units in Table 2.

7.1.2 Products ordered to this specification in SI units shall conform to the tensile strength requirements prescribed in MPa units [bracketed] in Table 2.

7.1.3 Acceptance or rejection based on mechanical properties shall depend only on the tensile strength.

7.1.4 The tension test specimens shall be taken so the longitudinal axis of the specimen is parallel to the direction of rolling.

8. Grain Size Requirements of Annealed Tempers

8.1 Grain size shall be the standard test for material of all thicknesses in annealed tempers, and acceptance or rejection shall depend on the grain sizes. The average grain size of each of two samples of annealed material as determined on a plane parallel to the surface of the material shall be within the limits prescribed in Table 3.

9. Rockwell Hardness

9.1 Rockwell hardness tests offer a quick and convenient method of checking copper-nickel-zinc and copper-nickel alloys of any temper for general conformity to the requirements for tensile strength or grain size. The approximate Rockwell hardness values for the rolled tempers are given in Table 2 and those for the annealed tempers of material 0.015 in. and over in thickness are given in Table 4, for general information and assistance in testing.

10. Dimensions and Permissible Variations

10.1 The inch-pound dimensions and tolerances for products covered by this specification shall be as prescribed in the current edition of Specification B 248, and the SI dimensions and tolerances covered by this specification shall be as prescribed in the current edition of Specification B 248M, with particular reference to Section 5 and the following tables of that specification:

10.2 *Thickness*—See 5.2, Tables 1 and 2. when special thickness tolerances for Copper Alloy UNS No. C 72500 are required see 5.2.3 and Table 3.

TABLE 1 Chemical Requirements

Copper Alloy UNS No.	Composition, %								
	Copper, incl Silver	Nickel, incl Cobalt	Lead, max	Iron, max	Manganese, max	Zinc	Tin	Chromium	Other Named Elements
C 70600	remainder	9.0–11.0[A]	0.05[B]	1.0–1.8	1.0	1.0[B] max	...	...	[B]
C 71000	remainder	19.0–23.0	0.05[B]	1.0 max	1.0	1.0[B] max	...	...	[B]
C 71500	remainder	29.0–33.0[A]	0.05[B]	0.40–1.0	1.0	1.0[B] max	...	...	[B]
C 72200	remainder	15.0–18.0	0.05[B]	0.50–1.0	1.0	1.0[B]	...	0.30–0.70	[B]
C 72500	remainder	8.5–10.5	0.05	0.6	0.2	0.5 max	1.8–2.8	...	...
C 73500	70.5–73.5	16.5–19.5	0.10	0.25 max	0.50	remainder	...	...	...
C 74000	69.0–73.5	9.0–11.0	0.10	0.25 max	0.50	remainder	...	...	...
C 74500	63.5–66.5	9.0–11.0	0.10	0.25 max	0.50	remainder	...	...	...
C 75200	63.5–66.5	16.5–19.5	0.05	0.25 max	0.50	remainder	...	...	...
C 76200	57.0–61.0	11.0–13.5	0.10	0.25 max	0.50	remainder	...	...	...
C 77000	53.5–56.5	16.5–19.5	0.05	0.25 max	0.50	remainder	...	...	...

[A] Copper plus elements with specific limits, 99.5 % min.

[B] When the product is for subsequent welding applications and so specified by the purchaser, zinc shall be 0.50 % max, lead 0.02 % max, phosphorus 0.02 % max, sulfur 0.02 % max, and carbon 0.05 % max.

TABLE 2 Tensile Strength Requirements and Approximate Rockwell Hardness Values for Rolled Tempers

NOTE—Plate is generally available in only the as hot-rolled (M20) tempers. Required properties for other tempers shall be agreed upon between manufacturer and purchaser at the time of placing the order.

Temper Designation		Tensile Strength, ksi[A] (MPa[B])		Approximate Rockwell Hardness[C]		
Standard	Former	Min	Max	G Scale	B Scale	Superficial 30-T
		Copper Alloy UNS No. C 70600†				
M20	as hot-rolled	40 [275]	62 [425]	...	...	...
H01	quarter hard	51 [350]	67 [460]	...	51–78	52–70
H02	half hard	58 [400]	72 [495]	...	66–81	61–72
H04	hard	71 [490]	83 [570]	...	76–86	67–74
H06	extra hard	73 [505]	85 [585]	...	80–88	71–77
H08	spring	78 [540]	88 [605]	...	83–91	72–78
		Copper Alloy UNS No. C 71000				
M20	as hot-rolled	38 [260]	56 [385]	...	...	...
H01	quarter hard	47 [325]	63 [435]	...	45–72	46–65
H02	half hard	56 [385]	70 [485]	...	64–78	59–69
H04	hard	67 [460]	79 [545]	...	76–84	67–73
H06	extra hard	72 [495]	84 [580]	...	79–87	69–75
H08	spring	76 [525]	87 [600]	...	82–88	71–75
		Copper Alloy UNS No. C 71500				
M20	as hot-rolled	45 [310]	65 [450]	...	...	...
H01	quarter hard	58 [400]	72 [495]	...	67–81	61–71
H02	half hard	66 [455]	80 [550]	...	76–85	67–74
H04	hard	75 [515]	88 [605]	...	83–89	72–76
H06	extra hard	80 [550]	92 [635]	...	85–91	73–77
H08	spring	84 [580]	94 [650]	...	87–91	74–77
		Copper Alloy UNS No. C 72200				
M20	as hot-rolled	42 [290]	62 [425]	...	...	...
H01	quarter hard	55 [380]	67 [460]	...	63–78	58–70
H02	half hard	58 [400]	72 [495]	...	66–85	61–73
H04	hard	71 [490]	85 [585]	...	76–88	67–78
H06	extra hard	73 [505]	90 [620]	...	79–90	69–78
H08	spring	78 [540]	91 [625]	...	81–91	71–79
		Copper Alloy UNS No. C 72500				
M20	as hot-rolled	50 [345]	70 [485]	...	...	...
H01	quarter hard	55 [380]	75 [515]	...	Up to 85	Up to 72
H02	half hard	65 [450]	80 [550]	...	70–90	62–75
H04	hard	75 [515]	90 [620]	...	75–90	66–75
H06	extra hard	80 [550]	95 [655]	...	80–95	70–80
H08	spring	85 [585]	100 [690]	...	85–95	72–80
H10	extra spring	90 [620]	105 [725]	...	87–95	76–80
H14	super spring	100 [690]	125 [860]	...	92 and over	78 and over
		Copper Alloy UNS No. C 73500				
M20	as hot-rolled	48 [330]	63 [435]	...	...	...
H01	quarter hard	56 [385]	69 [475]	20–47	66–80	60–70
H02	half hard	63 [435]	75 [515]	38–53	75–84	67–73
H04	hard	73 [505]	84 [580]	51–61	83–88	72–75
H06	extra hard	79 [545]	90 [620]	57–65	86–90	74–76
		Copper Alloy UNS No. C 74000				
M20	as hot-rolled	48 [330]	63 [435]	...	...	...
H01	quarter hard	55 [380]	70 [485]	...	60–80	...
H02	half hard	63 [435]	77 [530]	...	70–85	...
H04	hard	73 [505]	87 [600]	...	79–91	...
H06	extra hard	79 [545]	91 [625]	...	83–93	...
		Copper Alloy UNS No. C 74500				
M20	as hot-rolled	48 [330]	65 [450]	...	...	...
H01	hard	56 [385]	73 [505]	...	51–80	50–70
H02	half hard	67 [460]	82 [565]	...	72–87	65–75
H04	hard	80 [550]	94 [650]	...	85–92	73–78
H06	extra hard	89 [615]	102 [700]	...	90–94	76–79
H08	spring	95 [655]	108 [740]	...	92–96	77–80

TABLE 2 *Continued*

Temper Designation		Tensile Strength, ksi[A] (MPa)		Approximate Rockwell Hardness[C]		
Standard	Former	Min	Max	G Scale	B Scale	Superficial 30-T
		Copper Alloy UNS No. C 75200				
M20	as hot-rolled	52 [355]	65 [450]	...	...	...
H01	quarter hard	58 [400]	72 [495]	...	50–75	49–67
H02	half hard	66 [455]	80 [550]	...	68–82	62–72
H04	hard	78 [540]	91 [625]	...	80–90	70–76
H06	extra hard	86 [595]	98 [675]	...	87–94	74–79
H08	spring	90 [620]	101 [700]	...	89–96	75–80
		Copper Alloy UNS No. C 76200				
M20	as hot-rolled	55 [380]	75 [515]	...	...	...
H01	quarter hard	65 [450]	81 [560]	...	61–85	57–74
H02	half hard	75 [515]	91 [625]	...	78–91	69–77
H04	hard	90 [620]	105 [720]	...	90–95	76–79
H06	extra hard	99 [685]	114 [790]	...	94–98	79–81
H08	spring	107 [740]	122 [840]	...	97–100	80 and over
		Copper Alloy UNS No. C 77000				
M20	as hot-rolled	60 [415]	80 [550]	...	...	...
H01	quarter hard	69 [475]	87 [600]	23–62	70–88	63–75
H02	half hard	78 [540]	95 [655]	51–69	81–92	71–78
H04	hard	92 [635]	109 [750]	67–76	90–96	76–80
H06	extra hard	102 [700]	117 [810]	73–80	95–99	79–82
H08	spring	108 [740]	123 [850]	77–83	97–100	80 and over

[A] ksi = 1000 psi.
[B] See Appendix.
[C] Rockwell hardness values apply as follows: The B and G scale hardness values apply to metal 0.020 in. (0.508 mm) and over in thickness, and the 30-T scale hardness values apply to metal 0.012 in. (0.305 mm) and over in thickness.
[D] Standard designation defined in Practice B 601.

TABLE 3 Grain Size Requirements for Annealed Material

Copper Alloy UNS No.	Standard Temper Designation[B]	Grain Size, mm		
		Nominal	Min	Max
C 70600, C 71000, C 71500, C 72200, C 72500, C 73500, and C 76200	OS035	0.035	0.025	0.050
	OS015	0.015	[A]	0.025
C 74000, C 74500, C 75200, and C 77000	OS070	0.070	0.050	0.100
	OS035	0.035	0.025	0.050
	OS015	0.015	[A]	0.025

[A] Although no minimum grain size is required, this material shall be fully recrystallized.
[B] Standard designation defined in Practice B 601.

10.3 *Width:*
10.3.1 *Slit Metal and Slit Metal with Rolled Edges*—See 5.3, Table 4.
10.3.2 *Square-Sheared Metal*—See 5.3, Table 5.
10.3.3 *Sawed Metal*—See 5.3, Table 6.
10.4 *Length:*
10.4.1 *Specific and Stock Lengths With and Without Ends*—See Section 5.4, Table 7.
10.4.2 *Schedule of Lengths (Specific and Stock) with Ends*—See 5.4, Table 8.
10.4.3 *Length Tolerances for Square-Sheared Metal*—See 5.4, Table 9.
10.4.4 *Length Tolerances for Sawed Metal*—See 5.4, Table 10.
10.5 *Straightness:*
10.5.1 *Slit Metal or Slit Metal Either Straightened or Edge-Rolled*—See 5.5, Table 11.
10.5.2 *Square-Sheared Metal*—See 5.5, Table 12.
10.5.3 *Sawed Metal*—See 5.5, Table 13.
10.6 *Edges*—See 5.6.
10.6.1 *Square Edges*—See 5.6.1, Table 14.
10.6.2 *Rounded Corners*—See 5.6.2, Table 15.
10.6.3 *Rounded Edges*—See 5.6.3, Table 16.
10.6.4 *Full-Rounded Edges*—See 5.6.4, Table 17.

11. Keywords

11.1 copper-nickel plate; copper-nickel rolled bar; copper-nickel sheet; copper-nickel strip; copper-nickel-tin plate; copper-nickel-tin rolled bar; copper-nickel-tin sheet; copper-nickel-tin strip; copper-nickel-zinc plate; copper-nickel-zinc rolled bar; copper-nickel-zinc sheet; copper-nickel-zinc strip

TABLE 4 Approximate Rockwell Hardness of Annealed Material

Temper		Approximate Rockwell Hardness[A]		
Standard Designation	Nominal Grain Size, mm	B Scale	F Scale	Superficial 30-T
Copper Alloy UNS No. C 70600				
OS035	0.035	10–27	55–72	15–34
OS015	0.015	16–48	65–83	25–45
Copper Alloy UNS No. C 71000				
OS035	0.035	18–35	67–76	28–40
OS015	0.015	35–58	76–90	40–55
Copper Alloy UNS No. C 71500				
OS035	0.035	23–45	70–85	31–46
OS015	0.015	37–63	74–93	40–58
Copper Alloy UNS No. C 72200				
OS035	0.035	14–31	...	24–36
OS015	0.015	18–42	...	26–41
Copper Alloy UNS No. C 72500				
OS035	0.035	24–39	70–81	32–42
OS015	0.015	37–61	78–92	41–58
Copper Alloy UNS No. C 73500				
OS035	0.035	20–35	70–80	29–40
OS015	0.015	28–55	76–90	34–53
Copper Alloy UNS No. C 74000				
OS070	0.070	5–20	...	...
OS035	0.035	20–40	...	...
OS015	0.015	35–55	...	...
Copper Alloy UNS No. C 74500				
OS070	0.070	15–30	63–73	26–36
OS035	0.035	23–41	70–80	31–44
OS015	0.015	41–59	80–90	44–56
Copper Alloy UNS No. C 75200				
OS070	0.070	25–40	70–80	32–43
OS035	0.035	35–55	75–88	40–53
OS015	0.015	45–70	83–93	46–64
Copper Alloy UNS No. 76200				
OS035	0.035	20–35	70–80	...
OS015	0.015	28–55	76–90	...
Copper Alloy UNS No. C 77000				
OS070	0.070	29–45	72–83	35–46
OS035	0.035	37–60	76–91	41–57
OS015	0.015	47–73	84–98	47–65

[A] Rockwell hardness values apply as follows: The B and F scale hardness values apply to metal 0.020 in. (0.508 mm) and over in thickness and the 30-T scale hardness values apply to metal 0.015 in. (0.381 mm) and over in thickness.

APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 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.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B124: Standard Specification for Copper and Copper-Alloy Forging Rod, Bar, and Shapes

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THE EXECUTIVE DIRECTOR
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Designation: B 124 – 96

Standard Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes[1]

This standard is issued under the fixed designation B 124; 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. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope*

1.1 This specification establishes the requirements for copper and copper alloy rod, bar, and shapes intended for hot forging. The following copper and copper alloys are included:

Copper UNS Nos.	Copper Alloy UNS Nos.
C11000	C36500
C14500	C37700
C14700	C46400
	C48200
	C48500
	C61900
	C62300
	C63000
	C63200
	C64200
	C64210
	C65500
	C67500
	C77400

1.2 The values stated in inch-pound units are the standard.

1.3 This specification is the companion to SI Specification B 124M; therefore, no SI equivalents are presented in this specification.

2. Referenced Documents

2.1 *ASTM Standards:*

B 124M Specification for Copper and Copper-Alloy Forging Rod, Bar, and Shapes [Metric][2]

B 249 Specification for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, Shapes, and Forgings[2]

B 283 Specification for Copper and Copper-Alloy Die Forgings (Hot-Pressed)[2]

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[2]

E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes[3]

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Method)[3]

E 76 Test Methods for Chemical Analysis of Nickel-Copper Alloys[3]

E 121 Test Methods for Chemical Analysis of Copper-Tellurium Alloys[3]

E 478 Test Methods for Chemical Analysis of Copper Alloys[3]

2.2 *ISO Standard:*

No. 3110, Part 2 (TC 26 Ref. No. N 670 E/F) Determination of Aluminum Content: Flame Atomic Absorption Spectrometric Method[4]

3. Ordering Information

3.1 The contract or purchase order for product under this specification should include the following information:

3.1.1 ASTM designation and year of issue (B 124-XX),

3.1.2 Copper or Copper Alloy UNS No. (Section 5),

3.1.3 Form (Section 10),

3.1.4 Diameter or distance between parallel surfaces (Section 10),

3.1.5 Tolerances (Section 10),

3.1.6 Length (Section 10),

3.1.7 Quantity; total weight for each size and form,

3.1.8 When purchase is intended for a U.S. Government agency.

3.2 The following options are available and should be specified in the contract or purchase order when required:

3.2.1 Temper,

3.2.2 Mechanical properties,

3.2.3 Certification, and

3.2.4 Test report.

4. General Requirements

4.1 The following sections of Specification B 249 form a part of this specification:

4.1.1 Terminology,

4.1.2 Material and Manufacture,

4.1.3 Workmanship, Finish, and Appearance,

4.1.4 Sampling,

4.1.5 Number of Tests and Retests,

4.1.6 Specimen Preparation,

4.1.7 Test Methods,

4.1.8 Significance of Numerical Limits,

4.1.9 Inspection,

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.02 on Rod, Bar, Wire, Shapes and Forgings.

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

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

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

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

TABLE 1 Chemical Requirements

Copper or Copper Alloy UNS No.	Composition, %													
	Copper	Lead	Tin	Iron	Nickel (incl Co)	Aluminum	Silicon	Manganese	Zinc	Sulfur	Tellurium	Phosphorus	Arsenic	Copper Plus Elements with Specific Limits Present, min
C11000	99.90 min[A]	...	...	...	...	...	...	...	...	...	...	...	...	...
C14500[B]	99.90 min[C]	...	...	...	...	...	...	...	...	...	0.40–0.7	0.004–0.012[D]	...	...
C14700[E]	99.90 min[F]	...	...	...	...	...	...	...	...	0.20–0.50	...	...	...	...
C36500	58.0–61.0	0.25–0.7	0.25 max	0.15 max	...	...	...	...	remainder	...	...	...	...	...
C37700	58.0–61.0	1.5–2.5	...	0.30 max	...	...	...	...	remainder	...	...	...	...	...
C46400	59.0–62.0	0.20 max	0.5–1.0	0.15 max	...	...	...	...	remainder	...	...	...	...	...
C48200	59.0–62.0	0.40–1.0	0.50–1.0	0.15 max	...	...	...	...	remainder	...	...	...	...	...
C48500	59.0–62.0	1.3–2.2	0.5–1.0	0.15 max	...	...	...	...	remainder	...	...	...	...	...
C61900	remainder	0.02 max	0.6 max	3.0–4.5	...	8.5–10.0	...	...	0.8 max	...	...	...	...	99.5
C62300	remainder	...	0.6 max	2.0–4.0	1.0 max	8.5–11.0	0.25 max	0.50 max	...	...	...	...	...	99.5
C63000	remainder	...	0.20 max	2.0–4.0	4.0–5.5	9.0–11.0	0.25 max	1.5 max	0.30 max	...	...	...	...	99.5
C63200	remainder	0.02 max	...	3.5–4.3[G]	4.0–4.8	8.7–9.5	0.10 max	1.2–2.0	...	...	...	...	...	...
C64200	remainder	0.05 max	0.20 max	0.30 max	0.25 max	6.3–7.6	1.5–2.2	0.10 max	0.50 max	...	...	...	0.15 max	99.5
C64210	remainder	0.05 max	0.20 max	0.30 max	0.25 max	6.3–7.0	1.5–2.0	0.10 max	0.50 max	...	...	...	0.15 max	99.5
C65500	remainder	0.05 max	...	0.8 max	0.6 max	...	2.8–3.8	0.50–1.3	1.5 max	...	...	...	...	99.5
C67500	57.0–60.0	0.20 max	0.5–1.5	0.8–2.0	...	0.25 max	...	0.05–0.5	remainder	...	...	...	...	...
C77400	43.0–47.0	0.20 max	...	...	9.0–11.0	...	...	...	remainder	...	...	...	...	...

[A] Silver counts as copper.
[B] This includes oxygen-free tellurium copper which contains phosphorus in an amount agreed upon.
[C] This includes copper + silver + tellurium.
[D] Other deoxidizers may be used as agreed upon, in which case phosphorus need not be present.
[E] Includes oxygen-free or deoxidized grades with deoxidizers (such as phosphorus, boron, lithium, or others) in amount agreed upon.
[F] This includes copper plus silver plus sulfur.
[G] Iron content shall not exceed nickel content.

4.1.10 Rejection and Rehearing,
4.1.11 Certification,
4.1.12 Mill Test Report,
4.1.13 Packaging and Package Marking, and
4.1.14 Supplementary Requirements.

4.2 An identical section in this specification supplements the referenced section of Specification B 249.

5. Material and Manufacture

5.1 *Material:*

5.1.1 Product under this specification shall be produced from one of the following Copper or Copper Alloy UNS Nos.: C11000, C14500, C14700, C36500, C37700, C46400, C48200, C48500, C61900, C62300, C63000, C63200, C64200, C64210, C65500, C67500, C77400.

6. Chemical Composition

6.1 The material shall conform to the requirements in Table 1 for the specified copper or copper alloy.

6.1.1 These specification limits do not preclude the presence of other elements. Limits may be established and analysis required for unnamed elements by agreement between the manufacturer or supplier and the purchaser.

6.2 When the value of an element for a specified copper alloy is identified as the "Remainder," that "Remainder" value shall be determined as the difference between the sum of results for specified elements and 100 %.

6.3 When all elements in Table 1 for the specified copper alloy are determined the sum of results shall be as follows:

Copper Alloy UNS No.	Sum of Results Percent, % min
C36500, C46400, C48200, C48500	99.6
C37700, C61900, C62300, C63000, C63200, C64200, C64210, C65500, C67500, C77400	99.5

7. Temper

7.1 Product temper shall be subject to agreement between the manufacturer and the purchaser.

7.1.1 Product tempers normally available under this specification and as defined in Practice B 601 are M30, M20, and M50.

8. Mechanical Property Requirements

8.1 Mechanical properties, if any, are subject to agreement between the manufacturer and the purchaser.

9. Purchases for U.S. Government

9.1 When specified in the contract or purchase order, product purchased for agencies of the U.S. Government shall conform to the special government regulations specified in the Supplemental Requirements section.

10. Dimensions, Mass, and Permissible Variations

10.1 Except for shapes, length, and straightness, the dimensions and tolerances for product produced under this specification shall be as prescribed in the section titled "Diameter or Distance Between Parallel Surfaces" in Specification B 249 as follows:

10.1.1 *Diameter or Distance Between Parallel Surfaces:*

10.1.1.1 For M30 rod, Copper Alloy UNS Nos. C36500, C37700, C46400, C48200, C48500, C61900, C62300,

C63000, C63200, C64200, C64210, and C67500, refer to Table 4.

10.1.1.2 For M30 rod, Copper UNS Nos. C11000, C14500, and C14700 and Copper Alloy UNS Nos. C65500 and C77400, refer to Table 5.

10.1.1.3 For M20, round rod, refer to Table 6.

10.1.1.4 For M30, bar, refer to Table 4 for width tolerances for Copper Alloy UNS Nos. C36500, C37700, C46400, C48200, C48500, C61900, C62300, C63000, C63200, C64200, C64210, and C67500.

10.1.1.5 For M30 bar refer to Table 5 for width tolerances for Copper UNS Nos. C11000, C14500, and C14700 and Copper Alloy UNS Nos. C65500 and C77400.

10.1.1.6 For H50, rod, refer to Table 1 for Copper Alloy UNS Nos. C11000, C14500, C14700, C46400, C48200, and C48500.

10.1.1.7 For H50, rod, refer to Table 2 for Copper Alloy UNS Nos. C36500, C37700, C61900, C62300, C63000, C63200, C64200, C65500, C67500, and C77400.

10.1.1.8 For H50, bar, refer to Tables 7 and 10 for Copper Alloy UNS Nos. C11000, C14500, and C14700.

10.1.1.9 For H50, bar, refer to Tables 8 and 10 for Copper Alloy UNS Nos. C46400, C48200, and C48500.

10.1.1.10 For H50, bar, refer to Tables 9 and 11 for Copper Alloy UNS Nos. C36500, C37700, C61900, C62300, C63000, C63200, C64200, C65500, C67500, and C77400.

10.2 *Shapes*—The dimensional tolerances for shapes shall be agreed upon between the manufacturer and the purchaser and shall be specified in the order.

10.3 *Length*—Rod, bar, and shapes for forging when ordered to any length will be furnished in stock lengths, unless it is specifically stated in the purchase order that the lengths are to be specific.

10.3.1 Stock lengths for all rod, bar, and shapes for forging up to and including 1 in. (25.4 mm) in diameter shall be as listed in Table 2 but the weight of lengths less than the length ordered shall not exceed 40 % of any one shipment.

TABLE 2 Stock Lengths

Ordered Length	Shortest Permissible Length
ft	ft
12	6
10	6
8	4
6	4

The tolerance for the full-length pieces shall be plus 1 in. (25.4 mm).

10.3.2 For rod and bar for forging over 1 in. (25.4 mm) up to and including 2 in. (50.8 mm) in diameter the lengths shall be random lengths, from 4 to 12 ft (1.22 to 3.66 m).

10.3.3 Rod and bar for forging over 2 in. (50.8 mm) in diameter shall be ordered in special lengths.

10.4 *Straightness*—The material shall be straight, within 1 in. (25.4 mm) maximum depth of arc in 6 ft (1.83 m).

11. Test Methods

11.1 The test method(s) used for quality control or production control, or both, for the determination of conformance with product property requirements are discretionary.

11.1.1 The test method(s) used to obtain data for the preparation of certification or test report, or both, shall be made available to the purchaser on request.

11.2 *Chemical Analysis:*

11.2.1 Chemical composition shall, in case of disagreement, be determined as follows:

Element	Range, %	Test Method
Aluminum	0.005–12	ISO No. 3110 (AA)
	6–12	E 478
Arsenic	0–0.15	E 62
Copper	43–99.9	E 478
Iron	0.15–5	E 54
Lead	0.02–3	E 478 (AA)
Manganese	0.10–2.0	E 62
Phosphorus	0.004–0.7	E 62
Silicon	0.10–4	E 62
Sulfur	0–0.5	E 76 (Gravimetric)
Tellurium	0.40–1	E 121
Tin	0.2–1.5	E 478 (Photometric)
Zinc	0.3–1.5	E 478 (AA)
	2–40	E 478 (Titrametric)

11.2.2 Test methods for the determination of elements resulting from contractual or purchase order agreement shall be as agreed upon between the manufacturer or supplier and the purchaser.

12. Keywords

12.1 brass forging shapes; brass forgings; bronze forging shapes; bronze forgings; copper alloy forging bar; copper alloy forging materials; copper alloy forging rod; copper alloy forgings; copper forging bar; copper forging materials; copper forging rod; copper forging shapes; copper forgings; nickel silver forging shapes; nickel silver forgings

APPENDIX

(Nonmandatory Information)

X1. FORGING PRACTICE

X1.1 The data in Table X1.1 do not constitute a part of this specification. The suggested forging temperatures give the range suitable for hot forging of the alloys and the forgeability ratings illustrate the relative difference in ease of forging with forging brass being the most readily forgeable. For the relative strength of these alloy forgings, as hot pressed, see Specification B 283, Appendix 2, Table 4.

TABLE X1.1 Forging Temperatures and Forgeability

Copper or Copper Alloy UNS No.	Name	Suggested Forging Temperatures		Forgeability Rating[A]
		°F	K	
C 11000	Copper	1400–1700	1030–1200	65
C 14500	Copper-tellurium	1350–1650	1010–1170	65
C 14700	Copper-sulfur	1400–1600	750–875	65
C 36500	Leaded muntz metal, uninhibited	1200–1450	920–1060	100
C 37700	Forging brass	1200–1450	920–1060	100
C 46400	Naval brass	1200–1500	920–1090	90
C 48200	Medium leaded naval brass	1200–1500	920–1090	90
C 48500	Leaded naval brass	1200–1500	920–1090	90
C 61900	Aluminum bronze	1300–1600	980–1140	75
C 62300	Aluminum bronze, 9 %	1300–1600	980–1140	75
C 63000	Aluminum-nickel bronze	1450–1700	1060–1200	75
C 63200	Aluminum-nickel bronze	1450–1700	1060–1200	75
C 64200	Aluminum-silicon bronze	1300–1600	980–1140	75
C 64210	Aluminum-silicon bronze, 6.7 %	1300–1600	980–1140	75
C 65500	High-silicon bronze(A)	1300–1600	980–1140	40
C 67500	Manganese bronze (A)	1350–1550	1010–1120	80
C 77400	Nickel silver, 45-10	1300–1500	980–1090	85

[A] Relative forgeability rating takes into consideration such variable factors as pressure, die wear, and plasticity (hot). Since it is impractible to reduce these variables to common units, calibration in terms of a percentage of the most generally used alloy, forging brass (100 %), is considered the most practical basis for such ratings. The values shown represent the general opinion and are intended for information to enable the designer to better understand the forging characteristics of these various alloys. Intricate parts are more likely to be available in alloys having a high rating.

SUMMARY OF CHANGES

The section identifies the location of selected changes to this specification that have been incorporated since the 1994 issue.

(1) A change was made in the composition of lead for C36500 in Table 1.

Designation: B 124M – 96

Standard Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes [Metric][1]

This standard is issued under the fixed designation B 124M; 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. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope*

1.1 This specification establishes the requirements for copper and copper alloy rod, bar, and shapes intended for hot forging. The following copper and copper alloys are included:

Copper UNS Nos.	Copper Alloy UNS Nos.
C11000	C36500
C14500	C37700
C14700	C46400
	C48200
	C48500
	C61900
	C62300
	C63000
	C63200
	C64200
	C64210
	C65500
	C67500
	C77400

1.2 The values stated in SI units are the standard.

1.3 This specification is the companion to inch-pound Specification B 124.

2. Referenced Documents

2.1 *ASTM Standards:*

B 124 Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes[2]

B 249M Specification for General Requirements for Wrought Copper and Copper Alloy Rod, Bar, Shapes, and Forgings [Metric][2]

B 283 Specification for Copper and Copper-Alloy Die Forgings (Hot-Pressed)[2]

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[2]

E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes[3]

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Method)[3]

E 76 Test Methods for Chemical Analysis of Nickel-Copper Alloys[3]

E 121 Test Methods for Chemical Analysis of Copper-Tellurium Alloys[3]

E 478 Test Methods for Chemical Analysis of Copper Alloys[3]

2.2 *ISO Standard:*

No. 3110, Part 2 (TC 26 Ref. No. N 670 E/F)[4]

3. Ordering Information

3.1 The contract or purchase order for product under this specification should include the following information:

3.1.1 ASTM designation and year of issue (B 124M – XX),

3.1.2 Copper or Copper Alloy UNS No. (Section 5),

3.1.3 Form (Section 10),

3.1.4 Diameter or distance between parallel surfaces (Section 10),

3.1.5 Tolerances (Section 10),

3.1.6 Length (Section 10),

3.1.7 Quantity; total weight for each size and form, and

3.1.8 When purchase is intended for a U.S. Government agency.

3.2 The following options are available and should be specified in the contract or purchase order when required:

3.2.1 Temper,

3.2.2 Mechanical properties,

3.2.3 Certification, and

3.2.4 Test report.

4. General Requirements

4.1 The following sections of Specification B 249M form a part of this specification:

4.1.1 Terminology,

4.1.2 Material and Manufacture,

4.1.3 Workmanship, Finish, and Appearance,

4.1.4 Sampling,

4.1.5 Number of Tests and Retests,

4.1.6 Specimen Preparation,

4.1.7 Test Methods,

4.1.8 Significance of Numerical Limits,

4.1.9 Inspection,

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.02 on Rod, Bar, Wire, Shapes and Forgings.

Current edition approved Sept. 10, 1996. Published November 1996. Originally published as B 124M – 87. Last previous edition B 124M – 94.

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

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

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

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

TABLE 1 Chemical Requirements

Copper or Copper Alloy UNS No.	Composition, %												
	Copper	Lead	Tin	Iron	Nickel (incl Co)	Aluminum	Silicon	Manganese	Zinc	Sulfur	Tellurium	Phosphorus	Arsenic
C11000	99.90 min[A]	...	...	...	...	...	...	...	...	...	...	...	...
C14500[B]	99.90 min[C]	...	...	...	...	...	...	...	...	...	0.40–0.7	0.004–0.012[D]	...
C14700[E]	99.90 min[F]	...	...	...	...	...	...	...	...	0.20–0.50	...	...	...
C36500	58.0–61.0	0.25–0.7	0.25 max	0.15 max	...	...	...	...	remainder	...	...	...	...
C37700	58.0–61.0	1.5–2.5	...	0.30 max	...	...	...	...	remainder	...	...	...	...
C46400	59.0–62.0	0.20 max	0.5–1.0	0.15 max	...	...	...	...	remainder	...	...	...	...
C48200	59.0–62.0	0.40–1.0	0.50–1.0	0.15 max	...	...	...	...	remainder	...	...	...	...
C48500	59.0–62.0	1.3–2.2	0.5–1.0	0.15 max	...	...	...	...	remainder	...	...	...	...
C61900	remainder	0.02 max	0.6 max	3.0–4.5	...	8.5–10.0	...	...	0.8 max	...	...	...	...
C62300	remainder	...	0.6 max	2.0–4.0	1.0 max	8.5–11.0	0.25 max	0.50 max	...	...	...	...	...
C63000	remainder	...	0.20 max	2.0–4.0	4.0–5.5	9.0–11.0	0.25 max	1.5 max	0.30 max	...	...	...	...
C63200	remainder	0.02 max	...	3.5–4.3[G]	4.0–4.8	8.7–9.5	0.10 max	1.2–2.0	...	...	...	...	...
C64200	remainder	0.05 max	0.20 max	0.30 max	0.25 max	6.3–7.6	1.5–2.2	0.10 max	0.50 max	...	...	...	0.15 max
C64210	remainder	0.05 max	0.20 max	0.30 max	0.25 max	6.3–7.0	1.5–2.0	0.10 max	0.50 max	...	...	...	0.15 max
C65500	remainder	0.05 max	...	0.08 max	0.6 max	...	2.8–3.8	0.50–1.3	1.5 max	...	...	...	...
C67500	57.0–60.0	0.20 max	0.5–1.5	0.08–2.0	...	0.25 max	...	0.05–0.5	remainder	...	...	...	...
C77400	43.0–47.0	0.20 max	...	...	9.0–11.0	...	...	...	remainder	...	...	...	...

[A] Silver counts as copper.
[B] This includes oxygen-free tellurium copper which contains phosphorus in an amount agreed upon.
[C] This includes copper "silver" tellurium.
[D] Other deoxidizers may be used as agreed upon, in which case phosphorus need not be present.
[E] Includes oxygen-free or deoxidized grades with deoxidizers (such as phosphorus, boron, lithium, or others) in amount agreed upon.
[F] This includes copper plus silver plus sulfur.
[G] Iron content shall not exceed nickel content.

4.1.10 Rejection and Rehearing,
4.1.11 Certification,
4.1.12 Mill Test Report,
4.1.13 Packaging and Package Marking, and
4.1.14 Supplementary Requirements.

4.2 An identical section in this specification supplements the referenced section of Specification B 249.

5. Material and Manufacture

5.1 *Material:*

5.1.1 Product under this specification shall be produced from one of the following Copper or Copper Alloy UNS Nos.: C11000, C14500, C14700, C36500, C37700, C46400, C48200, C48500, C61900, C62300, C63000, C63200, C64200, C64210, C65500, C67500, and C77400.

6. Chemical Composition

6.1 The material shall conform to the requirements in Table 1 for the specified copper or copper alloy.

6.1.1 These specification limits do not preclude the presence of other elements. Limits may be established and analysis required for unnamed elements by agreement between the manufacturer or supplier and the purchaser.

6.2 When the value of an element for a specified copper alloy is identified as the "Remainder," that "Remainder" value shall be determined as the difference between the sum of results for specified elements and 100 %.

6.3 When all elements in Table 1 for the specified copper alloy are determined the sum of results shall be as follows:

Copper Alloy UNS No.	Sum of Results Percent, % min
C36500, C46400, C48200, C48500	99.6
C37700, C61900, C62300, C63000, C63200, C64200, C64210, C65500, C67500, C77400	99.5

7. Temper

7.1 Product temper shall be subject to agreement between the manufacturer and the purchaser.

7.1.1 Product tempers normally available under this specification and as defined in Practice B 601 are M30, M20, and M50.

8. Mechanical Property Requirements

8.1 Mechanical properties, if any, are subject to agreement between the manufacturer and the purchaser.

9. Purchases for U.S. Government

9.1 When specified in the contract or purchase order, product purchased for agencies of the U.S. Government shall conform to the special government regulations specified in the Supplemental Requirements section.

10. Dimensions, Mass, and Permissible Variations

10.1 Except for shapes, length, and straightness, the dimensions and tolerances for product produced under this specification shall be as prescribed in the section titled "Diameter or Distance Between Parallel Surfaces" in Specification B 249 as follows:

10.1.1 *Diameter or Distance Between Parallel Surfaces:*

10.1.1.1 For M30, rod, Copper Alloy UNS Nos. C36500, C37700, C46400, C48200, C48500, C61900, C62300, C63000, C63200, C64200, C64210, and C67500, refer to Table 4.

10.1.1.2 For M30, rod, Copper Alloy UNS Nos. C11000, C14500, C14700, C65500, and C77400, refer to Table 5.

10.1.1.3 For M20, round rod, refer to Table 6.

10.1.1.4 For M30, bar, refer to Table 4 for width toler-

TABLE 2 Stock Lengths

Ordered Length, m	Shortest Possible Length, m
4	2
3	2
2	1

ances for Copper Alloy UNS Nos. C36500, C37700, C46400, C48200, C48500, C61900, C62300, C63000, C63200, C64200, C64210, and C67500.

10.1.1.5 For M30, bar, refer to Table 5 for width tolerances for Copper Alloy UNS Nos. C11000, C14500, C14700, C65500, and C77400.

10.1.1.6 For H50, rod, refer to Table 1 for Copper Alloy UNS Nos. C11000, C14500, C14700, C46400, C48200, and C48500.

10.1.1.7 For H50, rod, refer to Table 2 for Copper Alloy UNS Nos. C36500, C37700, C61900, C62300, C63000, C63200, C64200, C65500, C67500, and C77400.

10.1.1.8 For H50, bar, refer to Tables 7 and 10 for Copper Alloy UNS Nos. C11000, C14500, and C14700.

10.1.1.9 For H50, bar, refer to Tables 8 and 10 for Copper Alloy UNS Nos. C46400, C48200, and C48500.

10.1.1.10 For H50, bar, refer to Tables 9 and 11 for Copper Alloy UNS Nos. C36500, C37700, C61900, C62300, C63000, C63200, C64200, C65500, C67500, and C77400.

10.1.2 *Shapes*—The dimensional tolerances for shapes shall be agreed upon between the manufacturer and the purchaser and shall be specified in the order.

10.2 *Length*—Rod, bar, and shapes for forging when ordered to any length will be furnished in stock lengths, unless it is specifically stated in the purchase order that the lengths are to be specific.

10.2.1 Stock lengths for all rod, bar, and shapes for forging up to and including 25 mm in diameter shall be as listed in Table 3 but the weight of lengths less than the length order shall not exceed 40 % of any one shipment. The tolerance for the full-length pieces shall be +25 mm.

10.2.2 For rod and bar for forging over 25 mm up to and including 50 mm in diameter the lengths shall be random lengths, from 1.2 to 3.7 m.

10.2.3 Rod and bar for forging over 50 mm in diameter shall be ordered in special lengths.

10.3 *Straightness*—The material shall be straight, within 25 mm maximum depth of arc in 1.8 m.

11. Test Methods

11.1 The test method(s) used for quality control or production control, or both, for the determination of conformance with product property requirements are discretionary.

11.1.1 The test method(s) used to obtain data for the preparation of certification or test report, or both, shall be made available to the purchaser on request.

11.2 *Chemical Analysis:*

11.2.1 Chemical composition shall, in case of disagreement, be determined as follows:

Element	Range, %	Test Method
Aluminum	0.005–12	ISO No. 3110 (AA)
	6–12	E 478
Arsenic	0–0.15	E 62
Copper	43–99.9	E 478
Iron	0.15–5	E 54
Lead	0.02–3	E 478 (AA)
Manganese	0.10–2.0	E 62
Phosphorus	0.004–0.7	E 62
Silicon	0.10–4	E 62
Sulfur	0–0.5	E 76 (Gravimetric)
Tellurium	0.40–1	E 121
Tin	0.2–1.5	E 478 (Photometric)
Zinc	0.3–1.5	E 478 (AA)
	2–40	E 478 (Titrimetric)

11.2.2 Test Methods for the determination of elements resulting from contractual or purchase order agreement shall be as agreed upon between the manufacturer or supplier and the purchaser.

12. Keywords

12.1 brass forging shapes; brass forgings; bronze forging shapes; bronze forgings; copper alloy forging bar; copper alloy forging materials; copper alloy forging rod; copper alloy forging shapes; copper alloy forgings; copper forging bar; copper forging materials; copper forging rod; copper forging shapes; copper forgings; nickel silver forging shapes; nickel silver forgings

APPENDIX

(Nonmandatory Information)

X1. FORGING PRACTICE

X1.1 The data in Table X1.1 do not constitute a part of this specification. The suggested forging temperatures give the range suitable for hot forging of the alloys and the forgeability ratings illustrate the relative difference in ease of forging with forging brass being the most readily forgeable. For the relative strength of these alloy forgings, as hot pressed, see Specification B 283, Appendix X2, Table X2.1.

TABLE X1.1 Forging Temperatures and Forgeability

Copper or Copper Alloy UNS No.	Name	Suggested Forging Temperatures, K	Forgeability Rating[A]
C11000	Copper	1030–1200	65
C14500	Copper-tellurium	1010–1170	65
C14700	Copper-sulfur	750–875	65
C36500	Leaded muntz metal, uninhibited	920–1060	100
C37700	Forging brass	920–1060	100
C46400	Naval brass	920–1090	90
C48200	Medium leaded naval brass	920–1090	90
C48500	Leaded naval brass	920–1090	90
C61900	Aluminum bronze	980–1140	75
C62300	Aluminum bronze, 9 %	980–1140	75
C63000	Aluminum-nickel bronze	1060–1200	75
C63200	Aluminum-nickel bronze	1060–1200	75
C64200	Aluminum-silicon bronze	980–1140	75
C64210	Aluminum-silicon bronze, 6.7 %	980–1140	75
C65500	High-silicon bronze (A)	980–1140	40
C67500	Manganese bronze (A)	1010–1120	80
C77400	Nickel silver, 45–10	980–1090	85

[A] Relative forgeability rating takes into consideration such variable factors as pressure, die wear, and plasticity (hot). Since it is impractible to reduce these variables to common units, calibration in terms of a percentage of the most generally used alloy, forging brass (100 %), is considered the most practical basis for such ratings. The values shown represent the general opinion and are intended for information to enable the designer to better understand the forging characteristics of these various alloys. Intricate parts are more likely to be available in alloys having a high rating.

SUMMARY OF CHANGES

The section identifies the location of selected changes to this specification that have been incorporated since the 1994 issue.

(1) A change was made in the composition of lead for C 36500 in Table 1.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B16: Standard Specification for Free-Cutting Brass Rod, Bar, and Shapes for Use in Screw Machines

CFR Section(s): 46 CFR 56.60-2

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 16 – 92

Standard Specification for Free-Cutting Brass Rod, Bar and Shapes for Use in Screw Machines[1]

This standard is issued under the fixed designation B 16; 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. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers free-cutting brass rod, bar, wire, and shapes of any specified cross section suitable for high-speed screw machine work. The material is Copper Alloy UNS No. C36000.[2]

1.2 Most rods made to this specification are furnished as straight lengths. However, sizes ½ in. and under may be furnished in coil form when requested.

NOTE 1—A complete metric companion, B 16M, has been developed. Therefore, no metric equivalents are presented in this specification.

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.

2.1.1 *ASTM Standards:*

B 249 Specification for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar and Shapes[3]

B 250 Specification for General Requirements for Wrought Copper-Alloy Wire[3]

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

E 478 Test Methods for Chemical Analysis of Copper Alloys[4]

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

3. Ordering Information

3.1 Material ordered to this specification shall contain information listed in the "Ordering Information" section of Specification B 249, plus the following:

3.1.1 Certification, when required,

3.1.2 Mill Test Report, when required, and

3.1.3 *Quantity*—Total weight, footage or number of pieces for each size.

4. General Requirements

4.1 Material supplied shall conform to the applicable requirements of the current edition of Specifications B 249 or B 250 unless otherwise prescribed in this specification.

5. Material and Manufacture

5.1 Refer to Specification B 249 for rod, bar and shape items and to Specification B 250 for wire products.

6. Chemical Composition

6.1 The material shall conform to the requirements of Table 1.

6.2 Either copper or zinc may be given as the remainder and may be taken as the difference between the sum of all elements analyzed and 100 %.

6.3 When all elements in the table are analyzed, their sum shall be 99.5 % minimum.

6.4 The specified limits do not preclude the presence of other elements. Limits may be established for unnamed elements by agreement between the manufacturer and the purchaser.

7. Temper

7.1 Material is available in the following tempers as defined in Practice B 601 as 060 (soft annealed), H02 (half hard) and H04 (hard).

7.2 HO2 (half hard) temper rods and bars shall be furnished unless otherwise specified in the contract or purchase order. Metal for applications requiring thread rolling should be so specified in the contract or purchase order. Mechanical requirements of drawn shapes shall be agreed upon between manufacturer and the purchaser.

8. Mechanical Properties

8.1 *Tensile*—The material shall conform to the requirement of Table 2.

8.2 *Rockwell Hardness*—The material shall conform to the requirements of Table 3.

8.3 The hardness test results, as far as they are specified, shall be the basis for acceptance based on mechanical properties. However, in case of disagreement, final acceptance or rejection shall be determined by the tensile test results.

9. Dimensions, Mass and Permissible Variations

9.1 Refer to the appropriate paragraphs in Specifications

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[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.02 on Rod, Bar, Shapes, Wire, and Forgings.

Current edition approved June 15, 1992. Published August 1992. Originally published as B 16 – 17 T. Last previous edition B 16 – 85[ε1].

[2] Refer to Practice E 527 for a description of the United Numbering System [UNS].

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

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

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

TABLE 1 Chemical Requirements

Element	Composition, %
Copper	60.0–63.0
Lead	2.5—3.7
Iron, max	0.35
Zinc	remainder

B 249 or B 250 with particular reference to the following tables of those specifications.

9.2 *Diameter or Distance between Parallel Surfaces:*

9.2.1 *Rod in Lengths: Round, Hexagonal, Octagonal*—Refer to Table 1 in Specification B 249.

9.2.2 *Rod in Coils: Round*—Refer to Table 1 in Specification B 250.

9.2.3 *Bar: Rectangular and Square*—Refer to Tables 8 and 10 in Specification B 249.

9.3 *Shapes*—The dimensional tolerances for shapes shall be by agreement between the manufacturer and the purchaser and shall be specified in the purchase order or contract.

9.4 *Length of Rod, Bar and Shapes*—Refer to Table 13 in Specification B 249.

9.5 *Straightness of Rod and Bar*—Refer to Table 16 in Specification B 249.

9.6 *Edge Contours*—Refer to the section of Specification B 249 entitled, "Edge Contours" and to Figs. 1, 2 and 3 of that specification.

10. Workmanship, Finish and Appearance

10.1 Refer to Specification B 249 for rod, bar, and shape items and to B 250 for wire products.

11. Sampling

11.1 Refer to Specification B 249 for rod, bar, and shape items and to Specification B 250 for wire products.

12. Number of Tests and Retests

12.1 Refer to Specification B 249 for rod, bar, and shape items and to Specification B 250 for wire products.

13. Specimen Preparation

13.1 Refer to Specification B 249 for the preparation of the appropriate rod, bar, and shape test specimen and to Specification B 250 for the appropriate wire test specimen.

14. Test Methods

14.1 Refer to Specification B 249 for the appropriate test method to be used for rod, bar, and shape items and to Specification B 250 for the appropriate test method to be used for wire products.

14.2 Chemical composition shall, in case of disagreement, be determined as follows:

Element	Test Methods
Copper	E 478
Lead	E 478 Atomic absorption
Iron	E 478
Zinc	E 478 Titrimetric

15. Significance of Numerical Limits

15.1 Refer to Specification B 249 for rod, bar, and shape items and to Specification B 250 for wire products.

TABLE 2 Tensile Requirements

Temper Designation		Diameter or Distance Between Parallel Surfaces, in.		Tensile Strength min ksi[A]	Yield Strength at 0.5 % Extension under load min ksi[A]	Elongation in 4× Diameter or Thickness of Specimen, min, %[B]
Standard	Former					
		Rod				
O60	soft anneal	1 and under		48	20	15
		over 1 to 2, incl		44	18	20
		over 2		40	15	25
H02	half-hard	½ and under		57	25	7[C]
		over ½ to 1, incl[D]		55	25	10
		over 1 to 2, incl		50	20	15
		over 2 to 4, incl		45	15	20
		over 4		40	15	20
H04	hard	1/16 to 3/16, incl		80	45	...
		over 3/16 to ½, incl		70	35	4
		over ½ to ¾, incl		65	30	6
		Bar				
		Thickness, in.	Width, in.			
O60	soft anneal	1 and under	6 and under	44	18	20
		over 1	6 and under	40	15	25
H02	half-hard	½ and under	1 and under	50	25	10
		½ and under	over 1 to 6	45	17	15
		over ½ to 2	2 and under	45	17	15
		over ½ to 2	over 2 to 6	40	15	20
		over 2	over 2 to 4	40	15	20

[A] ksi = 1000 psi.

[B] In any case a minimum gage length of 1 in. shall be used.

[C] For material furnished in coils the elongation shall be 4 %, min.

[D] If specified for thread rolling applications the minimum tensile strength shall be 52 ksi.

TABLE 3 Hardness Requirements

NOTE—Rockwell tests are not established for diameters less than ½ in.

Temper Designation		Diameter or Distance Between Parallel Surfaces, in.		Rockwell B Hardness Determined on the Cross-Section Midway Between Surface and Center	
Standard	Former				
		Rod			
				Round	Hexagonal and Octagonal
O60	soft anneal	½ and over		10–45	10–45
H02	half-hard	½ to 1, incl[A]		60–80	55–80
		over 1 to 2, incl		55–75	45–80
		over 2 to 3, incl		45–70	40–65
		over 3 to 4, incl		40–65	35–60
		over 4		25 min	25 min
		Bar			
		Thickness, in.	Width, in.		
O60	soft anneal	½ and over	½ and over	10–35	
H02	half-hard	½ and under	1 and under	45–85	
		½ and under	over 1 to 6	35–70	
		over ½ to 2, incl	2 and under	40–80	
			over 2 to 6	35–70	
		over 2	over 2 to 4	35–70	

[A] If specified for thread rolling application the Rockwell B hardness shall be 55 to 75.

16. Inspection

16.1 Refer to Specification B 249 for rod, bar, and shape items and to Specification B 250 for wire products.

17. Rejection and Rehearing

17.1 Refer to Specification B 249 for rod, bar, and shape items and to Specification B 250 for wire products.

18. Certification

18.1 Refer to Specification B 249 for rod, bar, and shape items and to Specification B 250 for wire products.

19. Mill Test Reports

19.1 Refer to Specification B 249 for rod, bar, and shape items and to Specification B 250 for wire products.

20. Packaging and Package Marking

20.1 Refer to Specification B 249 for rod, bar, and shape items and to Specification B 250 for wire products.

21. Supplementary Requirements

21.1 Refer to Specification B 249 for rod, bar, and shape items and to Specification B 250 for wire products.

22. Keywords

22.1 free-cutting brass bar; free-cutting brass rod; free-cutting brass shapes; screw machine rod

Designation: B 16M – 92

Standard Specification for Free-Cutting Brass Rod, Bar, and Shapes for Use in Screw Machines [Metric][1]

This standard is issued under the fixed designation B 16M; 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. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers free-cutting brass rod, bar, wire and shapes of any specified cross section suitable for high-speed screw machine work. The material is Copper Alloy UNS No. C36000.[2]

1.2 Most rods made to this specification are furnished as straight lengths. However, sizes 12 mm and under may be furnished in coil form when requested.

NOTE 1—This specification is the metric companion to Specification B 16.

2. Referenced Documents

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

2.1.1 *ASTM Standards:*

B 249M Specification for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar and Shapes (Metric)[3]

B 250M Specification for General Requirements for Wrought Copper-Alloy Wire (Metric)[3]

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

E 478 Test Methods for Chemical Analysis of Copper Alloys[4]

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

3. General Requirements

3.1 For the following information, refer to Specification B 249M for rod, bar and shape items and to Specification B 250M for wire items:

3.1.1 Terminology,
3.1.2 Ordering information,
3.1.3 Materials and manufacture,
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 reports,
3.1.14 Product marking,
3.1.15 Packaging and package marking, and
3.1.16 Supplementary requirements.

4. Chemical Composition

4.1 The material of manufacture shall conform to the requirements of Table 1.

4.2 Either copper or zinc may be given as the remainder and may be taken as the difference between the sum of all elements analyzed and 100 %.

4.3 When all elements in the table are analyzed, their sum shall be 99.5 % minimum.

4.4 The specified limits do not preclude the presence of other elements. Limits may be established for unnamed elements by agreement between the manufacturer and the purchaser.

5. Physical Properties

5.1 *Temper*—Material is available in the following tempers as defined in Practice B 601 as O60 (soft annealed), H02 (half hard), and H04 (hard).

5.2 H02 (half hard) temper rods and bars shall be furnished unless otherwise specified in the contract or purchase order. Metal for applications requiring thread rolling should be so specified in the contract or purchase order. Mechanical requirements of drawn shapes shall be agreed upon between the manufacturer and the buyer.

6. Mechanical Properties

6.1 *Tensile*—The material shall conform to the requirements of Table 2.

6.2 *Rockwell Hardness*—The material shall conform to the requirements of Table 3.

TABLE 1 Chemical Requirements

Element	Composition, %
Copper	60.0–63.0
Lead	2.5–3.7
Iron, max	0.35
Zinc	remainder

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.02 on Rod, Bar, Wire Shapes and Forgings.

Current edition approved Nov. 15, 1992. Published January 1993. Originally published as B 16M – 80. Last previous edition B 16M – 85.

[2] Refer to Practice E 527 for a description of the Unified Numbering System (UNS).

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

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

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

TABLE 2 Tensile Requirements

Temper Designation		Diameter or Distance Between Parallel Surfaces, mm	Tensile Strength, min, MPa	Yield Strength at 0.5 % Extension Under Load, min, MPa	Elongation,[A] min, %
Standard	Former	Rod			
O60	soft anneal	25 and under	330	140	15
		over 25 to 50, incl	305	125	20
		over 50	275	105	25
H02	half hard	12 and under	395	170	7[B]
		over 12 to 25, incl	380	170	10
		over 25 to 50, incl	345	140	15
		over 50 to 100, incl	310	105	20
		over 100	275	105	20
H04	hard	1.6 to 4, incl	550	310	...
		over 4 to 12, incl	480	240	4
		over 12 to 18, incl	450	205	6
		Bar			
Standard	Former	Thickness, mm	Width, mm		
O60	soft anneal	25 and under	15 and under	305	125	20
		over 25	15 and under	275	105	25
H02	half hard	12 and under	25 and under	345	170	10
		12 and under	over 25 to 150	310	115	15
		over 12 to 50	50 and under	310	115	15
		over 12 to 50	over 50 to 150	275	105	20
		over 50	over 50 to 100	275	105	20

[A] Elongation values are based on a gage length of 5.65 times the square root of the area for dimensions greater than 2.5 mm.
[B] For material furnished in coils the elongation shall be 4 %, min.
[C] If specified for thread rolling applications the minimum tensile strength shall be 350 MPa.

TABLE 3 Hardness Requirements

Temper Designation		Diameter or Distance Between Parallel Surfaces, mm	Rockwell B Hardness Determined on the Cross Section Midway Between Surface and Center	
		Rod		
Standard	Former		Round	Hexagonal and Octagonal
O60	soft anneal	12 and over	10 to 45	10 to 45
H02	half hard	12 to 25, incl[A]	60 to 80	55 to 80
		25 to 50, incl	55 to 75	45 to 80
		50 to 75, incl	45 to 70	40 to 65
		75 to 100, incl	40 to 65	35 to 60
		over 100	25 min	25 min
		Bar		
Standard	Former	Thickness, mm	Width, mm	
O60	soft anneal	12 and over	12 and over	10 to 35
H02	half hard	12 and under	25 and under	45 to 85
		12 and under	over 25 to 150	35 to 70
		over 12 to 50, incl	50 and under	40 to 80
			over 50 to 150	35 to 70
		over 50	over 50 to 100	35 to 70

[A] If specified for thread rolling application, the Rockwell B hardness shall be 55 to 75.

6.3 The hardness test results, as far as they are specified, shall be the basis for acceptance based on mechanical properties. However, in case of disagreement, final acceptance or rejection shall be determined by the tensile test results.

7. Dimensions, Mass, and Permissible Variations

7.1 Refer to the appropriate paragraphs in Specifications B 249M or B 250M with particular reference to the following tables of those specifications.

7.2 *Diameter or Distance between Parallel Surfaces:*

7.2.1 *Rod in Lengths: Round, Hexagonal, Octagonal*—Refer to Table 1 in Specification B 249M.

7.2.2 *Rod in Coils: Round*—Refer to Table 1 in Specification B 250M.

7.2.3 *Bar: Rectangular and Square*—Refer to Tables 8 and 10 in Specification B 249M.

7.3 *Shapes*—The dimensional tolerances for shapes shall be as agreed upon between the manufacturer and the purchaser and shall be specified in the purchase order or contract.

7.4 *Length of Rod, Bar and Shapes*—Refer to Table 13 in Specification B 249M.

7.5 *Straightness of Rod and Bar*—Refer to Table 16 in Specification B 249M.

7.6 *Edge Contours*—Refer to the "Edge Contours" section of Specification B 249M and to Figs. 1, 2, and 3.

9. Test Methods

9.1 Refer to Specification B 249M for the appropriate mechanical and physical test method, or both, to be used for Rod, Bar and Shape items and to Specification B 250M for the appropriate test method to be used for Wire products.

9.2 Chemical composition shall, in case of disagreement, be determined as follows:

Element	Test Method
Copper	E 478
Lead	E 478 Atomic absorption
Iron	E 478
Zinc	E 478 Titrimetric

10. Keywords

10.1 free-cutting brass bar; free-cutting brass rod; free-cutting brass shapes; screw machine rod

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name:

CFR Section(s):

Standards Body:

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 209 – 96

Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate[1]

This standard is issued under the fixed designation B 209; 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[2] covers aluminum and aluminum-alloy flat sheet, coiled sheet, and plate, in the alloys (Note 1) and tempers shown in Tables 2 and 3, and in the following finishes:

1.1.1 Plate in all alloys and sheet in heat-treatable alloys: mill finish.

1.1.2 Sheet in nonheat-treatable alloys: mill finish, one-side bright mill finish, standard one-side bright finish, and standard two-sides bright finish.

NOTE 1—Throughout this specification use of the term *alloy* in the general sense includes aluminum as well as aluminum alloy.

NOTE 2—See Specification B 632 for tread plate.

1.2 Alloy and temper designations are in accordance with ANSI H35.1. The equivalent Unified Numbering System alloy designations are those of Table 1 preceded by A9, for example, A91100 for aluminum 1100 in accordance with Practice E 527.

1.3 A complete metric companion to Specification B 209 has been developed—B 209 M; therefore, no metric equivalents are presented in this specification.

1.4 For acceptance criteria for inclusion of new aluminum and aluminum alloys in this specification, see Annex A2.

2. Referenced Documents

2.1 The following documents of the issue in effect on the date of material purchase, unless otherwise noted, form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*

B 548 Method for Ultrasonic Inspection of Aluminum-Alloy Plate for Pressure Vessels[3]

B 557 Test Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products[3]

B 594 Practice for Ultrasonic Inspection of Aluminum-Alloy Wrought Products for Aerospace Applications[3]

B 597 Practice for Heat Treatment of Aluminum Alloys[3]

B 660 Practices for Packaging/Packing of Aluminum and Magnesium Products[3]

B 666/B 666M Practice for Identification Marking of Aluminum Products[3]

E 3 Methods of Preparation of Metallographic Specimens[4]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[5]

E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys[6]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[6]

E 101 Test Method for Spectrographic Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[7]

E 227 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[6]

E 290 Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials[4]

E 407 Test Methods for Microetching Metals and Alloys[4]

E 527 Practice for Numbering Metals and Alloys (UNS)[8]

E 607 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique, Nitrogen Atmosphere[9]

E 716 Practices for Sampling Aluminum and Aluminum Alloys for Spectrochemical Analysis[9]

E 1004 Test Method for Electromagnetic (Eddy-Current) Measurements of Electrical Conductivity[10]

E 1251 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Argon

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[1] This specification is under the jurisdiction of ASTM Committee B-7 on Light Metals and Alloys, and is the direct responsibility of Subcommittee B07.03 on Aluminum-Alloy Wrought Products.

Current edition approved Aug. 10, 1996. Published September 1996. Originally published as B 209 – 46 T. Last previous edition B 209 – 95.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SB-209 in Section II of that Code.

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

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

[5] *Annual Book of ASTM Standards*, Vol 14.02.

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

[7] Discontinued. See *1995 Annual Book of ASTM Standards*, Vol 03.05.

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

[9] *Annual Book of ASTM Standards*, Vol 03.06.

[10] *Annual Book of ASTM Standards*, Vol 03.03.

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

Atmosphere, Point-to-Plane, Unipolar Self-Initiating Capacitor Discharge[9]

G 47 Test Method for Determining Susceptibility to Stress-Corrosion Cracking of High Strength Aluminum Alloy Products[11]

G 66 Test Method for Visual Assessment of Exfoliation Corrosion Susceptibility of 5XXX Series Aluminum Alloys (Asset Test)[11]

Method of Test for Exfoliation Corrosion Susceptibility in 7XXX Series Copper-Containing Aluminum Alloys (Exco Test) (G34-72)[12]

2.3 *ANSI Standards:*

H35.1 Alloy and Temper Designation Systems for Aluminum[13]

H35.2 Dimensional Tolerances for Aluminum Mill Products[13]

2.4 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[14]

2.5 *Military Specification:*

MIL-H-6088 Heat Treatment of Aluminum Alloys[14]

2.6 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[14]

3. Terminology

3.1 *Definitions:*

3.1.1 *sheet*—a rolled product that is rectangular in cross section with thickness less than 0.250 in. but not less than 0.006 in. and with slit, sheared, or sawed edges.

3.1.2 *alclad sheet*—composite sheet comprised of an aluminum-alloy core having on both surfaces (if on one side only, alclad one-side sheet) a metallurgically bonded aluminum or aluminum-alloy coating that is anodic to the core, thus electrolytically protecting the core against corrosion.

3.1.3 *coiled sheet*—sheet in coils with slit edges.

3.1.4 *flat sheet*—sheet with sheared, slit, or sawed edges, which has been flattened or leveled.

3.1.5 *mill finish sheet*—sheet having a nonuniform finish which may vary from sheet to sheet and within a sheet, and may not be entirely free from stains or oil.

3.1.6 *one-side bright mill finish sheet*—sheet having a moderate degree of brightness on one side, and a mill finish on the other.

3.1.7 *standard one-side bright finish sheet*— sheet having a uniform bright finish on one side, and a mill finish on the other.

3.1.8 *standard two-sides bright finish sheet*— sheet having a uniform bright finish on both sides.

3.1.9 *plate*—a rolled product that is rectangular in cross section with thickness not less than 0.250 in., and with sheared or sawed edges.

3.1.10 *alclad plate*—composite plate comprised of an aluminum-alloy core having on both surfaces (if on one side only, alclad one-side plate) a metallurgically bonded aluminum or aluminum alloy coating that is anodic to the core, thus electrolytically protecting the core against corrosion.

3.1.11 *parent coil or plate*—a coil of sheet or a plate that has been processed to final temper as a single unit and subsequently cut into two or more smaller coils or individual sheets or into smaller plates to provide the required width or length, or both.

3.1.12 *producer*—the primary manufacturer of the material.

3.1.13 *supplier*—includes only the category of jobbers and distributors as distinct from producers.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *capable of*—The term *capable of* as used in this specification means that the test need not be performed by the producer of the material. However, should testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material to this specification shall include the following information:

4.1.1 This specification designation (which includes the number, the year, and the revision letter, if applicable),

4.1.2 Quantity in pieces or pounds,

4.1.3 Alloy (7.1),

4.1.4 Temper (9.1),

4.1.5 Finish for sheet in nonheat-treatable alloys (Section 1),

4.1.6 For sheet, whether flat or coiled,

4.1.7 Dimensions (thickness, width, and length or coil size),

4.1.8 Tensile property limits and dimensional tolerances for sizes not covered in Table 2 or Table 3 of this specification and in ANSI H35.2, respectively.

4.2 Additionally, orders for material to this specification shall include the following information when required by the purchaser:

4.2.1 Whether supply of one of the pairs of tempers where shown in Table 2, H14 or H24, H34 or H24 is specifically excluded (Table 2, footnote *D*),

4.2.2 Whether heat treatment in accordance with Practice B 597 is required (8.2),

4.2.3 Whether bend tests are required (12.1),

4.2.4 Whether testing for stress-corrosion cracking resistance of alloy 2124-T851 is required (13.1),

4.2.5 Whether ultrasonic inspection for aerospace or pressure vessel applications is required (Section 17),

4.2.6 Whether inspection or witness of inspection and tests by the purchaser's representative is required prior to material shipment (18.1),

4.2.7 Whether certification is required (Section 22),

4.2.8 Whether marking for identification is required (20.1), and

4.2.9 Whether Practices B 660 applies and, if so, the levels of preservation, packaging, and packing required (23.121.1).

5. Responsibility for Quality Assurance

5.1 *Responsibility for Inspection and Tests*—Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test

[11] *Annual Book of ASTM Standards*, Vol 03.02.

[12] The applicable edition in the use of this specification is G34–72—available in the Related Materials section (gray pages) of the *Annual Book of ASTM Standards*, Vol 02.02.

[13] Available in the Related Materials section (gray pages) of the *Annual Book of ASTM Standards*, Vol 02.02.

[14] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 1 Chemical Composition Limits[A,B,C]

Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Titanium	Other Elements[D]		Aluminum
									Each	Total[E]	
1060	0.25	0.35	0.05	0.03	0.03	...	0.05	0.03	0.03[F]	...	99.60 min[G]
1100	0.95 Si + Fe		0.05–0.20	0.05	...	...	0.10	...	0.05	0.15	99.00 min[G]
1230[H]	0.70 Si + Fe		0.10	0.05	0.05	...	0.10	0.03	0.03[F]	...	99.30 min[G]
2014	0.50–1.2	0.7	3.9–5.0	0.40–1.2	0.20–0.8	0.10	0.25	0.15	0.05	0.15	remainder
Alclad 2014						2014 clad with 6003					
2024	0.50	0.50	3.8–4.9	0.30–0.9	1.2–1.8	0.10	0.25	0.15	0.05	0.15	remainder
Alclad 2024						2024 clad with 1230					
2124	0.20	0.30	3.8–4.9	0.30–0.9	1.2–1.8	0.10	0.25	0.15	0.05	0.15	remainder
2219	0.20	0.30	5.8–6.8	0.20–0.40	0.02	...	0.10	0.02–0.10	0.05[I]	0.15[I]	remainder
Alclad 2219						2219 clad with 7072					
3003	0.6	0.7	0.05–0.20	1.0–1.5	...	...	0.10	...	0.05	0.15	remainder
Alclad 3003						3003 clad with 7072					
3004	0.30	0.7	0.25	1.0–1.5	0.8–1.3	...	0.25	...	0.05	0.15	remainder
Alclad 3004						3004 clad with 7072					
3005	0.6	0.7	0.30	1.0–1.5	0.20–0.6	0.10	0.25	0.10	0.05	0.15	remainder
3105	0.6	0.7	0.30	0.30–0.8	0.20–0.8	0.20	0.40	0.10	0.05	0.15	remainder
5005	0.30	0.7	0.20	0.20	0.50–1.1	0.10	0.25	...	0.05	0.15	remainder
5010	0.40	0.7	0.25	0.10–0.30	0.20–0.6	0.15	0.30	0.10	0.05	0.15	remainder
5050	0.40	0.7	0.20	0.10	1.1–1.8	0.10	0.25	...	0.05	0.15	remainder
5052	0.25	0.40	0.10	0.10	2.2–2.8	0.15–0.35	0.10	...	0.05	0.15	remainder
5083	0.40	0.40	0.10	0.40–1.0	4.0–4.9	0.05–0.25	0.25	0.15	0.05	0.15	remainder
5086	0.40	0.50	0.10	0.20–0.7	3.5–4.5	0.05–0.25	0.25	0.15	0.05	0.15	remainder
5154	0.25	0.40	0.10	0.10	3.1–3.9	0.15–0.35	0.20	0.20	0.05	0.15	remainder
5252	0.08	0.10	0.10	0.10	2.2–2.8	...	0.05	...	0.03[F]	0.10[F]	remainder
5254	0.45 Si + Fe		0.05	0.01	3.1–3.9	0.15–0.35	0.20	0.05	0.05	0.15	remainder
5454	0.25	0.40	0.10	0.50–1.0	2.4–3.0	0.05–0.20	0.25	0.20	0.05	0.15	remainder
5456	0.25	0.40	0.10	0.50–1.0	4.7–5.5	0.05–0.20	0.25	0.20	0.05	0.15	remainder
5457	0.08	0.10	0.20	0.15–0.45	0.8–1.2	...	0.05	...	0.03[F]	0.10[F]	remainder
5652	0.40 Si + Fe		0.04	0.01	2.2–2.8	0.15–0.35	0.10	...	0.05	0.15	remainder
5657	0.08	0.10	0.10	0.03	0.6–1.0	...	0.05	...	0.02[J]	0.05[J]	remainder
6003[H]	0.35–1.0	0.6	0.10	0.8	0.8–1.5	0.35	0.20	0.10	0.05	0.15	remainder
6061	0.40–0.8	0.7	0.15–0.40	0.15	0.8–1.2	0.04–0.35	0.25	0.15	0.05	0.15	remainder
Alclad 6061						6061 clad with 7072					
7008[H]	0.10	0.10	0.05	0.05	0.7–1.4	0.12–0.25	4.5–5.5	0.05	0.05	0.10	remainder
7011[H]	0.15	0.20	0.05	0.10–0.30	1.0–1.6	0.05–0.20	4.0–5.5	0.05	0.05	0.15	remainder
7072[H]	0.7 Si + Fe		0.10	0.10	0.10	...	0.8–1.3	...	0.05	0.15	remainder
7075	0.40	0.50	1.2–2.0	0.30	2.1–2.9	0.18–0.28	5.1–6.1	0.20	0.05	0.15	remainder
Alclad 7075						7075 clad with 7072					
7008 Alclad 7075						7075 clad with 7008					
7011 Alclad 7075						7075 clad with 7011					
7178	0.40	0.50	1.6–2.4	0.30	2.4–3.1	0.18–0.28	6.3–7.3	0.20	0.05	0.15	remainder
Alclad 7178						7178 clad with 7072					

[A] Limits are in weight percent maximum unless shown as a range or stated otherwise.

[B] Analysis shall be made for the elements for which limits are shown in this table.

[C] For purposes of determining conformance to these limits, an observed value or a calculated value attained from analysis shall be rounded to the nearest unit in the last righthand place of figures used in expressing the specified limit, in accordance with the rounding-off method of Practice E 29.

[D] *Others* includes listed elements for which no specific limit is shown as well as unlisted metallic elements. The producer may analyze samples for trace elements not specified in the specification. However, such analysis is not required and may not cover all metallic *Others* elements. Should any analysis by the producer or the purchaser establish that an *Others* element exceeds the limit of *Each* or that the aggregate of several *Others* elements exceeds the limit of *Total*, the material shall be considered nonconforming.

[E] *Other Elements*—Total shall be the sum of unspecified metallic elements 0.010 % or more, rounded to the second decimal before determining the sum.

[F] Vanadium 0.05 max. The total for other elements does not include vanadium.

[G] The aluminum content shall be calculated by subtracting from 100.00 % the sum of all metallic elements present in amounts of 0.010 % or more each, rounded to the second decimal before determining the sum.

[H] Composition of cladding alloy as applied during the course of manufacture. Samples from finished sheet or plate shall not be required to conform to these limits.

[I] Vanadium 0.05–0.15, zirconium 0.10–0.25. The total for other elements does not include vanadium and zirconium.

[J] Gallium 0.03 max, vanadium 0.05 max. The total for other elements does not include vanadium or gallium.

requirements specified herein. The producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser in the order or at the time of contract signing. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that material conforms to prescribed requirements.

5.2 *Lot Definition*— An inspection lot shall be defined as follows:

5.2.1 For heat-treated tempers, an inspection lot shall consist of an identifiable quantity of material of the same mill form, alloy, temper, and thickness traceable to a heat-treat lot or lots, and subjected to inspection at one time.

5.2.2 For nonheat-treated tempers, an inspection lot shall consist of an identifiable quantity of material of the same mill form, alloy, temper, and thickness subjected to inspection at one time.

6. General Quality

6.1 Unless otherwise specified, the material shall be supplied in the mill finish and shall be uniform as defined by the requirements of this specification and shall be commercially sound. Any requirement not so covered is subject to negotiation between producer and purchaser.

6.2 Each sheet and plate shall be examined to determine conformance to this specification with respect to general quality and identification marking. On approval of the purchaser, however, the producer may use a system of statistical quality control for such examinations.

7. Chemical Composition

7.1 *Limits*—The sheet and plate shall conform to the chemical composition limits specified in Table 1. Conformance shall be determined by the producer by analyzing samples taken at the time the ingots are poured, or samples taken from the finished or semifinished product. If the producer has determined the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product.

NOTE 3—It is standard practice in the United States aluminum industry to determine conformance to the chemical composition limits prior to further processing of ingots into wrought products. Due to the continuous nature of the process, it is not practical to keep a specific ingot analysis identified with a specific quantity of finished material.

7.2 *Number of Samples*—The number of samples taken for determination of chemical composition shall be as follows:

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

7.2.2 When samples are taken from the finished or semifinished product, a sample shall be taken to represent each 4000 lb, or fraction thereof, of material in the lot, except that not more than one sample shall be required per piece.

7.3 *Methods of Sampling*—Samples for determination of chemical composition shall be taken in accordance with one of the following methods:

7.3.1 Samples for chemical analysis shall be taken by drilling, sawing, milling, turning, or clipping a representative piece or pieces to obtain a prepared sample of not less than 75 g. Sampling shall be in accordance with Practice E 55.

7.3.2 Sampling for spectrochemical analysis shall be in accordance with Practices E 716. Samples for other methods of analysis shall be suitable for the form of material being analyzed and the type of analytical method used.

NOTE 4—It is difficult to obtain a reliable analysis of each of the components of clad materials using material in its finished state. A reasonably accurate determination of the core composition can be made if the cladding is substantially removed prior to analysis. The cladding composition is more difficult to determine because of the relatively thin layer and because of diffusion of core elements to the cladding. The correctness of cladding alloy used can usually be verified by a combination of metallographic examination and spectrochemical analysis of the surface at several widely separated points.

7.4 *Methods of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (Test Methods E 34), or spectrochemical (Test Methods E 101, E 227, E 607, and E 1251) methods. Other methods may be used only when no published ASTM method is available. In case of dispute, the methods of analysis shall be agreed upon between the producer and purchaser.

8. Heat Treatment

8.1 Unless specified in 8.2, producer or supplier heat treatment for the applicable tempers in Table 3 shall be in accordance with MIL-H-6088.

8.2 When specified, heat treatment of applicable tempers in Table 3 shall be in accordance with Practice B 597.

9. Tensile Properties of Material as Supplied

9.1 *Limits*—The sheet and plate shall conform to the requirements for tensile properties as specified in Table 2 and Table 3 for nonheat-treatable and heat-treatable alloys, respectively.

9.1.1 Tensile property limits for sizes not covered in Table 2 or Table 3 shall be as agreed upon between the producer and purchaser and shall be so specified in the contract or purchase order.

9.2 *Number of Samples*—One sample shall be taken from each end of each parent coil, or parent plate, but no more than one sample per 2000 lb of sheet or 4000 lb of plate, or part thereof, in a lot shall be required. Other procedures for selecting samples may be employed if agreed upon between the producer and purchaser.

9.3 *Test Specimens*— Geometry of test specimens and the location in the product from which they are taken shall be as specified in Test Methods B 557.

9.4 *Test Methods*— The tension test shall be made in accordance with Test Methods B 557.

10. Producer Confirmation of Heat-Treat Response

10.1 In addition to the requirements of 9.1, material in the O or F temper of alloys 2014, Alclad 2014, 2024, Alclad 2024, 1½ % Alclad 2024, Alclad one-side 2024, 1½ % Alclad one-side 2024, 6061, and Alclad 6061 shall, upon proper solution heat treatment and natural aging at room temperature, develop the properties specified in Table 3 for T42 temper material. The natural aging period at room temperature shall be not less than 4 days, but samples of material may be tested prior to 4 days aging, and if the material fails to conform to the requirements of T42 temper material, the tests may be repeated after completion of 4 days aging without prejudice.

10.2 Also, material in the O or F temper of alloys 2219, Alclad 2219, 6061, 7075, Alclad 7075, Alclad one-side 7075, 7008 Alclad 7075, 7178, and Alclad 7178 shall, upon proper solution heat treatment and precipitation heat treatment, develop the properties specified in Table 3 for T62 temper material.

10.3 Mill-produced material in the O or F tempers of 7008 Alclad 7075 shall, upon proper solution heat treatment and

stabilizing, be capable of attaining the properties specified in Table 3 for the T76 temper.

10.4 *Number of Specimens*—The number of specimens from each lot of O temper material and F temper material to be tested to verify conformance with 10.1-10.3 shall be as specified in 9.2.

11. Heat Treatment and Reheat-Treatment Capability

11.1 Mill-produced material in the O or F temper of alloys 2014, Alclad 2014, 2024, Alclad 2024, 1½ % Alclad 2024, Alclad one-side 2024, 1½ % Alclad one-side 2024, 6061, and Alclad 6061 (without the subsequent imposition of cold work or forming operations) shall, upon proper solution heat treatment and natural aging at room temperature, develop the properties specified in Table 3 for T42 temper material. The natural aging period at room temperature shall be not less than 4 days, but samples of material may be tested prior to 4 days aging, and if the material fails to conform to the requirements of T42 temper material, the tests may be repeated after completion of 4 days aging without prejudice.

11.2 Mill-produced material in the O or F temper of alloys 2219, Alclad 2219, 6061, 7075, Alclad 7075, Alclad one-side 7075, 7008 Alclad 7075, 7178, and Alclad 7178 (without the subsequent imposition of cold work or forming operations) shall, upon proper solution heat treatment and precipitation heat treatment, develop the properties specified in Table 3 for T62 temper material.

11.3 Mill-produced material in the O or F temper of 7008 Alclad 7075 (without the subsequent imposition of cold work or forming operations) shall, upon proper solution heat treatment and stabilizing, be capable of attaining the properties specified in Table 3 for the T76 temper.

11.4 Mill-produced material in the following alloys and tempers shall, after proper resolution heat treatment and natural aging for four days at room temperature, be capable of attaining the properties specified in Table 3 for the T42 temper.

Alloys	Tempers
2014 and Alclad 2014	T3, T4, T451, T6, T651
2024 and Alclad 2024	T3, T4, T351, T81, T851
1½ % Alclad 2024, Alclad One-side 2024 and 1½ % Alclad One-side 2024	T3, T351, T81, T851

NOTE 5—Beginning with the 1974 revision 6061 and Alclad 6061 T4, T451, T6, and T651 were deleted from this paragraph because experience has shown that reheat-treated material may develop large recrystallized grains and may fail to develop the tensile properties shown in Table 3.

11.5 Mill-produced material in the following alloys and tempers shall, after proper resolution heat treatment and precipitation heat treatment, be capable of attaining the properties specified in Table 3 for the T62 temper.

Alloys	Tempers
2219 and Alclad 2219	T31, T351, T81, T851
7075	T6, T651, T73, T7351, T76, T7651
Alclad 7075, 7008 Alclad 7075, 7178, and Alclad 7178	T6, T651, T76, T7651
Alclad One-side 7075	T6, T651

11.6 Mill-produced material in the following alloys and tempers and T42 temper material shall, after proper precipitation heat treatment, be capable of attaining the properties specified in Table 3 for the aged tempers listed below.

Alloy and Temper	Temper after Aging
2014 and Alclad 2014-T3, T4, T42, T451	T6, T6, T respectively
2024, Alclad 2024, 1½ % Alclad 2024, Alclad One-side 2024 and 1½ % Alclad One-side 2024-T3, T351, T361, T42	T81, T851, T861, T62 or T72, respectively
2219 and Alclad 2219-T31, T351, T37	T81, T851, T87, respectively
6061 and Alclad 6061-T4, T451, T42	T6, T651, T62, respectively

12. Bend Properties

12.1 *Limits*—Sheet and plate shall be capable of being bent cold through an angle of 180° around a pin having a diameter equal to N times the thickness of the sheet or plate without cracking, the value of N being as prescribed in Table 2 for the different alloys, tempers, and thicknesses. The test need not be conducted unless specified on the purchase order.

12.2 *Test Specimens*— When bend tests are made, the specimens for sheet shall be the full thickness of the material, approximately ¾ in. in width, and when practical, at least 6 in. in length. Such specimens may be taken in any direction and their edges may be rounded to a radius of approximately 1/16 in. if desired. For sheet less than ¾ in. in width, the specimens should be the full width of the material.

12.3 *Test Methods*— The bend tests shall be made in accordance with Test Method E 290 except as stated otherwise in 12.2.

13. Stress-Corrosion Resistance

13.1 When specified on the purchase order or contract, alloy 2124-T851, 2219-T851, and 2219-T87 plate shall be subjected to the test specified in 13.3 and shall exhibit no evidence of stress-corrosion cracking. One sample shall be taken from each parent plate in each lot and a minimum of three adjacent replicate specimens from this sample shall be tested. The producer shall maintain records of all lot acceptance test results and make them available for examination at the producer's facility.

13.2 Alloy 7075 in the T73-type and T76-type tempers, and alloys Alclad 7075, 7008 Alclad 7075, 7178, and Alclad 7178 in the T76-type tempers, shall be capable of exhibiting no evidence of stress-corrosion cracking when subjected to the test specified in 13.3.

13.2.1 For lot-acceptance purposes, resistance to stress-corrosion cracking for each lot of material shall be established by testing the previously selected tension-test samples to the criteria shown in Table 4.

13.2.2 For surveillance purposes, each month the producer shall perform at least one test for stress-corrosion resistance in accordance with 13.3 on each applicable alloy-temper for each thickness range 0.750 in. and over listed in Table 3, produced that month. Each sample shall be taken from material considered acceptable in accordance with lot-acceptance criteria of Table 4. A minimum of three adjacent replicate specimens shall be taken from each sample and tested. The producer shall maintain records of all lots so tested and make them available for examination at the producer's facility.

13.3 The stress-corrosion cracking test shall be performed on plate 0.750 in. and over in thickness as follows:

13.3.1 Specimens shall be stressed in tension in the short transverse direction with respect to grain flow and held at constant strain. For alloy 2124-T851, the stress levels shall be 50 % of the specified minimum long transverse yield strength. For alloy 2219-T851 and T87, the stress levels shall be 75 % of the specified minimum long transverse yield strength. For T73-type tempers, the stress level shall be 75 % of the specified minimum yield strength and for T76-type it shall be 25 ksi.

13.3.2 The stress-corrosion test shall be made in accordance with Test Method G 47.

13.3.3 There shall be no visual evidence of stress-corrosion cracking in any specimen, except that the retest provisions of 19.2 shall apply.

14. Exfoliation-Corrosion Resistance

14.1 Alloys 5083, 5086, and 5456 in the H116 temper shall be capable of exhibiting no evidence of exfoliation corrosion when subjected to the test described in Test Method G 66.

NOTE 6—Alloys 5083, 5086, and 5456 should not be used for continuous service at temperatures exceeding 150°F because of susceptibility to stress corrosion cracking. In addition, stress corrosion susceptibility is increased by cold forming.

14.1.1 For lot-acceptance purposes, the acceptability of each lot of material in the alloys and temper listed in 14.1 shall be determined by the producer by metallographic examination of one sample per lot selected from midsection at one end of a random sheet or plate. The microstructure of the sample from each production lot shall be compared to that of a producer-established reference photomicrograph of acceptable material in the same thickness range which is characterized by being predominantly free of a continuous grain boundary network of aluminum-magnesium (Mg_2Al_3) precipitate. A reference photomicrograph taken at 500× shall be established for each of the thickness ranges shown in Table 2 in which materials are produced and shall be taken from a sample within that thickness range. A longitudinal section perpendicular to the rolled surface shall be prepared for metallographic examination (see Methods E 3, symbol E in Fig. 1) and shall be microetched for metallographic examination using 40 % phosphoric acid etch for 3 min at 95°F or using etchant No. 6 in accordance with Test Methods E 407, Table 2, for 2 min. The metallographic examination shall be conducted at 500× magnification. If the microstructure shows evidence of aluminum-magnesium precipitate in excess of the producer-established reference photomicrograph of acceptable material, the lot is either rejected or tested for exfoliation-corrosion resistance in accordance with 14.1. The sample for corrosion test should be selected in the same manner specified for metallographic tests and shall be taken from the same sheet or plate used for metallographic test. Specimens prepared from the sample shall be full section thickness, except that for material 0.101 in. or more in thickness, 10 % of the thickness shall be removed, by machining, from one as-rolled surface. Both the machined surface and the remaining as-rolled surface shall be evaluated after exposure to the test solution. Production practices shall not be changed after establishment of the reference micrograph except as provided in 14.1.3.

14.1.2 The producer shall maintain at the producing facility all records relating to the establishment of reference photomicrographs and production practices.

14.1.3 Significant changes in production practices that alter the microstructures of the alloy shall require qualification of the practice in accordance with 14.1.1.

14.2 Alloys 7075, Alclad 7075, 7008 Alclad 7075, 7178, and Alclad 7178, in the T76-type tempers, shall be capable of exhibiting no evidence of exfoliation corrosion equivalent to or in excess of that illustrated by Category B in Fig. 2 of Method of Test for Exfoliation Corrosion Susceptibility in 7XXX Series Copper Containing Aluminum Alloys (Exco Test) (G34-72)[14] when subjected to the test in 14.3.

14.2.1 For lot-acceptance purposes, resistance to exfoliation corrosion for each lot of material in the alloys and tempers listed in 14.2 shall be established by testing the previously selected tension-test samples to the criteria shown in Table 4.

14.2.2 For surveillance purposes, each month the producer shall perform at least one test for exfoliation-corrosion resistance for each alloy for each thickness range listed in Table 3, produced that month. The samples for test shall be selected at random from material considered acceptable in accordance with the lot-acceptance criteria of Table 4. The producer shall maintain records of all surveillance test results and make them available for examination.

14.3 The test for exfoliation-corrosion resistance shall be made in accordance with Method of Test for Exfoliation Corrosion Susceptibility in 7XXX Series Copper Containing Aluminum Alloys (Exco Test) (G34-72)[14] and the following:

14.3.1 The specimens shall be a minimum of 2 in. by 4 in. with the 4-in. dimension in a plane parallel to the direction of final rolling. They shall be full-section thickness specimens of the material except that for material 0.101 in. or more in thickness, 10 % of the thickness shall be removed by machining one surface. The cladding of alclad sheet of any thickness shall be removed by machining the test surface; the cladding on the back side (nontest surface) of the specimen for any thickness of alclad material shall also either be removed or masked off. For machined specimens, the machined surface shall be evaluated by exposure to the test solution.

15. Cladding

15.1 Preparatory to rolling alclad sheet and plate to the specified thickness, the aluminum or aluminum-alloy plates which are bonded to the alloy ingot or slab shall be of the composition shown in Table 1 and shall each have a thickness not less than that shown in Table 5 for the alloy specified.

15.2 When the thickness of the cladding is to be determined on finished material, not less than one transverse sample approximately ¾ in. in length shall be taken from each edge and from the center width of the material. Samples shall be mounted to expose a transverse cross section and shall be polished for examination with a metallurgical microscope. Using 100× magnification, the maximum and minimum cladding thickness on each surface shall be measured in each of five fields approximately 0.1 in. apart for each sample. The average of the ten values (five minima plus five maxima) on each sample surface is the average cladding thickness and shall

meet the minimum average and, when applicable, the maximum average specified in Table 5.

16. Dimensional Tolerances

16.1 *Thickness*—The thickness of flat sheet, coiled sheet, and plate shall not vary from that specified by more than the respective permissible variations prescribed in Tables 3.1 and Tables 3.13 of ANSI H35.2. Permissible variations in thickness of plate specified in thicknesses exceeding 6 in. shall be the subject of agreement between the purchaser and the producer or the supplier at the time the order is placed.

16.2 *Length, Width, Lateral Bow, Squareness, and Flatness*—Coiled sheet shall not vary in width or in lateral bow from that specified by more than the permissible variations prescribed in Tables 3.5 and Tables 3.6, respectively, of ANSI H35.2. Flat sheet and plate shall not vary in width, length, lateral bow, squareness, or flatness by more than the permissible variations prescribed in the following tables of ANSI H35.2 except that where the tolerances for sizes ordered are not covered by this standard the permissible variations shall be the subject of agreement between the purchaser and the producer or the supplier at the time the order is placed:

Table No.	Title
3.2	width, sheared flat sheet and plate
3.3	width and length, sawed flat sheet and plate
3.4	length, sheared flat sheet and plate
3.7	lateral bow, flat sheet and plate
3.8	squareness, flat sheet and plate
3.11	flatness, flat sheet
3.12	flatness, sawed or sheared plate

16.3 Dimensional tolerances for sizes not covered in ANSI H35.2 shall be as agreed upon between the producer and purchaser and shall be so specified in the contract or purchase order.

16.4 *Sampling for Inspection*—Examination for dimensional conformance shall be made to ensure conformance to the tolerance specified.

17. Internal Quality

17.1 When specified by the purchaser at the time of placing the order, plate 0.500 in. to 4.500 in. in thickness and up to 2000 lb in maximum weight in alloys 2014, 2024, 2124, 2219, 7075, and 7178, both bare and Alclad where applicable, shall be tested in accordance with Practice B 594 to the discontinuity acceptance limits of Table 6.

17.2 When specified by the purchaser at the time of placing the order, plate 0.500 in. in thickness and greater for ASME pressure vessel applications in alloys 1060, 1100, 3003, Alclad 3003, 3004, Alclad 3004, 5052, 5083, 5086, 5154, 5254, 5454, 5456, 5652, 6061, and Alclad 6061 shall be tested in accordance with Method B 548. In such cases the material will be subject to rejection if the following limits are exceeded unless it is determined by the purchaser that the area of the plate containing significant discontinuities will be removed during the subsequent fabrication process or that the plate may be repaired by welding:

17.2.1 If the longest dimension of the marked area representing a discontinuity causing a complete loss of back reflection (95 % or greater) exceeds 1.0 in.

17.2.2 If the length of the marked area representing a discontinuity causing an isolated ultrasonic indication without a complete loss of back reflection (95 % or greater) exceeds 3.0 in.

17.2.3 If each of two marked areas representing two adjacent discontinuities causing isolated ultrasonic indications without a complete loss of back reflection (95 % or greater) is longer than 1.0 in., and if they are located within 3.0 in. of each other.

18. Source Inspection

18.1 If the purchaser desires that his representative inspect or witness the inspection and testing of the material prior to shipment, such agreement shall be made by the purchaser and producer as part of the purchase contract.

18.2 When such inspection or witness of inspection and testing is agreed upon, the producer shall afford the purchaser's representative all reasonable facilities to satisfy him that the material meets the requirements of this specification. Inspection and tests shall be conducted so there is no unnecessary interference with the producer's operations.

19. Retest and Rejection

19.1 If any material fails to conform to all of the applicable requirements of this specification, the inspection lot shall be rejected.

19.2 When there is evidence that a failed specimen was not representative of the inspection lot and when no other sampling plan is provided or approved by the purchaser through the contract or purchase order, at least two additional specimens shall be selected to replace each test specimen that failed. All specimens so selected for retest shall meet the requirements of the specification or the lot shall be subject to rejection.

19.3 Material in which defects are discovered subsequent to inspection may be rejected.

19.4 If material is rejected by the purchaser, the producer or supplier is responsible only for replacement of material to the purchaser. As much as possible of the rejected material shall be returned to the producer or supplier by the purchaser.

20. Identification Marking of Product

20.1 When specified on the purchase order or contract, all sheet and plate shall be marked in accordance with Practice B 666.

20.2 In addition, alloys in the 2000 and 7000 series in the T3-, T4-, T6-, T7-, and T8-type tempers and, when specified, 6061-T6 and T651 shall be marked with the lot number in at least one location on each piece.

20.3 The requirements specified in 20.1 and 20.2 are minimum; marking systems that involve added information, larger characters, and greater frequencies are acceptable under this specification.

21. Packaging and Package Marking

21.1 The material shall be packaged to provide adequate protection during normal handling and transportation and each package shall contain only one size, alloy, and temper of material unless otherwise agreed. The type of packaging and gross weight of containers shall, unless otherwise agreed, be at

the producer's or supplier's discretion, provided that they are such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

21.2 Each shipping container shall be marked with the purchase order number, material size, specification number, alloy and temper, gross and net weights, and the producer's name or trademark.

21.3 When specified in the contract or purchase order, material shall be preserved, packaged, and packed in accordance with the requirements of Practices B 660. The applicable levels shall be as specified in the contract or order. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

22. Certification

22.1 The producer or supplier shall, on request, furnish tothe purchaser a certificate stating that each lot has been sampled, tested, and inspected in accordance with this specification, and has met the requirements.

23. Keywords

23.1 aluminum alloy; aluminum-alloy plate; aluminum-alloy sheet

TABLE 2 Mechanical Property Limits for Nonheat-Treatable Alloy[A,B]

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
			Aluminum 1060				
O	0.006–0.019	8.0	14.0	2.5	...	15	...
	0.020–0.050	8.0	14.0	2.5	...	22	...
	0.051–3.000	8.0	14.0	2.5	...	25	...
H12[C] or H22[C]	0.017–0.050	11.0	16.0	9.0	...	6	...
	0.051–2.000	11.0	16.0	9.0	...	12	...
H14[C] or H24[C]	0.009–0.019	12.0	17.0	10.0	...	1	...
	0.020–0.050	12.0	17.0	10.0	...	5	..
	0.051–1.000	12.0	17.0	10.0	...	10	...
H18[C] or H26[C]	0.006–0.019	14.0	19.0	11.0	...	1	...
	0.020–0.050	14.0	19.0	11.0	...	4	...
	0.051–0.162	14.0	19.0	11.0	...	5	...
H18[C] or H28[C]	0.006–0.019	16.0	...	12.0	...	1	...
	0.020–0.050	16.0	...	12.0	...	3	...
	0.051–0.128	16.0	...	12.0	...	4	...
H112	0.250–0.499	11.0	...	7.0	...	10	...
	0.500–1.000	10.0	...	5.0	...	20	...
	1.001–3.000	9.0	...	4.0	...	25	...
F	0.250–3.000	...	...	...	...	...	...
			Aluminum 1100				
O	0.006–0.019	11.0	15.5	3.5	...	15	0
	0.020–0.031	11.0	15.5	3.5	...	20	0
	0.032–0.050	11.0	15.5	3.5	...	25	0
	0.051–0.249	11.0	15.5	3.5	...	30	0
	0.250–3.000	11.0	15.5	3.5	...	28	0
H12[C] or H22[C]	0.017–0.019	14.0	19.0	11.0	...	3	0
	0.020–0.031	14.0	19.0	11.0	...	4	0
	0.032–0.050	14.0	19.0	11.0	...	6	0
	0.051–0.113	14.0	19.0	11.0	...	8	0
	0.114–0.499	14.0	19.0	11.0	...	9	0
	0.500–2.000	14.0	19.0	11.0	...	12	0
H14[C] or H24[C]	0.009–0.012	16.0	21.0	14.0	...	1	0
	0.013–0.019	16.0	21.0	14.0	...	2	0
	0.020–0.031	16.0	21.0	14.0	...	3	0
	0.032–0.050	16.0	21.0	14.0	...	4	0
	0.051–0.113	16.0	21.0	14.0	...	5	0
	0.114–0.499	16.0	21.0	14.0	...	6	0
	0.500–1.000	16.0	21.0	14.0	...	10	0
H16[C]	0.006–0.019	19.0	24.0	17.0	...	1	4

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
or	0.020–0.031	19.0	24.0	17.0	...	2	4
H26[C]	0.032–0.050	19.0	24.0	17.0	...	3	4
	0.051–0.162	19.0	24.0	17.0	...	4	4
H18[C]	0.006–0.019	22.0	...	...	...	1	...
or	0.020–0.031	22.0	...	...	...	2	...
H28[C]	0.032–0.050	22.0	...	...	...	3	...
	0.051–0.128	22.0	...	...	...	4	...
H112	0.250–0.499	13.0	...	7.0	...	9	...
	0.500–2.000	12.0	...	5.0	...	14	...
	2.001–3.000	11.5	...	4.0	...	20	...
F[D]	0.250–3.000	...	...	...	...	...	...
		Alloy 3003					
O	0.006–0.007	14.0	19.0	5.0	...	14	0
	0.008–0.012	14.0	19.0	5.0	...	18	0
	0.013–0.031	14.0	19.0	5.0	...	20	0
	0.032–0.050	14.0	19.0	5.0	...	23	0
	0.051–0.249	14.0	19.0	5.0	...	25	0
	0.250–3.000	14.0	19.0	5.0	...	23	...
H12[C]	0.017–0.019	17.0	23.0	12.0	...	3	0
or	0.020–0.031	17.0	23.0	12.0	...	4	0
H22[C]	0.032–0.050	17.0	23.0	12.0	...	5	0
	0.051–0.113	17.0	23.0	12.0	...	6	0
	0.114–0.161	17.0	23.0	12.0	...	7	0
	0.162–0.249	17.0	23.0	12.0	...	8	0
	0.250–0.499	17.0	23.0	12.0	...	9	...
	0.500–2.000	17.0	23.0	12.0	...	10	...
H14[C]	0.009–0.012	20.0	26.0	17.0	...	1	0
or	0.013–0.019	20.0	26.0	17.0	...	2	0
H24[C]	0.020–0.031	20.0	26.0	17.0	...	3	0
	0.032–0.050	20.0	26.0	17.0	...	4	0
	0.051–0.113	20.0	26.0	17.0	...	5	0
	0.114–0.161	20.0	26.0	17.0	...	6	2
	0.162–0.249	20.0	26.0	17.0	...	7	2
	0.250–0.499	20.0	26.0	17.0	...	8	...
	0.500–1.000	20.0	26.0	17.0	...	10	...
H16[C]	0.006–0.019	24.0	30.0	21.0	...	1	4
or	0.020–0.031	24.0	30.0	21.0	...	2	4
H26[C]	0.032–0.050	24.0	30.0	21.0	...	3	4
	0.051–0.162	24.0	30.0	21.0	...	4	6
H18[C]	0.006–0.019	27.0	...	24.0	...	1	...
or	0.020–0.031	27.0	...	24.0	...	2	...
H28[C]	0.032–0.050	27.0	...	24.0	...	3	...
	0.051–0.128	27.0	...	24.0	...	4	...
H112	0.250–0.499	17.0	...	10.0	...	8	...
	0.500–2.000	15.0	...	6.0	...	12	...
	2.001–3.000	14.5	...	6.0	...	18	...
F[D]	0.250–3.000	...	...	...	...	...	...
		Alclad Alloy 3003					
O	0.006–0.007	13.0	18.0	4.5	...	14	...
	0.008–0.012	13.0	18.0	4.5	...	18	...
	0.013–0.031	13.0	18.0	4.5	...	20	...
	0.032–0.050	13.0	18.0	4.5	...	23	...
	0.051–0.249	13.0	18.0	4.5	...	25	...
	0.250–0.499	13.0	18.0	4.5	...	23	...
	0.500–3.000	14.0[E]	19.0[E]	5.0[E]	...	23	...
H12[C]	0.017–0.031	16.0	22.0	11.0	...	4	...
or	0.032–0.050	16.0	22.0	11.0	...	5	...
H22[C]	0.051–0.113	16.0	22.0	11.0	...	6	...
	0.114–0.161	16.0	22.0	11.0	...	7	...
	0.162–0.249	16.0	22.0	11.0	...	8	...

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
	0.250–0.499	16.0	22.0	11.0	...	9	...
	0.500–2.000	17.0[E]	23.0[E]	12.0[E]	...	10	...
H14[C]	0.009–0.012	19.0	25.0	16.0	...	1	...
or	0.013–0.019	19.0	25.0	16.0	...	2	...
H24[C]	0.020–0.031	19.0	25.0	16.0	...	3	...
	0.032–0.050	19.0	25.0	16.0	...	4	...
	0.051–0.113	19.0	25.0	16.0	...	5	...
	0.114–0.161	19.0	25.0	16.0	...	6	...
	0.162–0.249	19.0	25.0	16.0	...	7	...
	0.250–0.499	19.0	25.0	16.0	...	8	...
	0.500–1.000	20.0[E]	26.0[E]	17.0[E]	...	10	...
H16[C]	0.006–0.019	23.0	29.0	20.0	...	1	...
or	0.020–0.031	23.0	29.0	20.0	...	2	...
H26[C]	0.032–0.050	23.0	29.0	20.0	...	3	...
	0.051–0.162	23.0	29.0	20.0	...	4	...
H18	0.006–0.019	26.0	...	...	...	1	...
	0.020–0.031	26.0	...	...	...	2	...
	0.032–0.050	26.0	...	...	...	3	...
	0.051–0.128	26.0	...	...	...	4	...
H112	0.250–0.499	16.0	...	9.0	...	8	...
	0.500–2.000	15.0[E]	...	6.0 [E]	...	12	...
	2.001–3.000	14.5[E]	...	6.0[E]	...	18	...
F[D]	0.250–3.000	...	...	...	...	...	...
		Alloy 3004					
O	0.006–0.007	22.0	29.0	8.5	...	...	...
	0.008–0.019	22.0	29.0	8.5	...	10	0
	0.020–0.031	22.0	29.0	8.5	...	14	0
	0.032–0.050	22.0	29.0	8.5	...	16	0
	0.051–0.249	22.0	29.0	8.5	...	18	0
	0.250–3.000	22.0	29.0	8.5	...	16	...
H32[C]	0.017–0.019	28.0	35.0	21.0	...	1	0
or	0.020–0.031	28.0	35.0	21.0	...	3	1
H22[C]	0.032–0.050	28.0	35.0	21.0	...	4	1
	0.051–0.113	28.0	35.0	21.0	...	5	2
	0.114–2.000	28.0	35.0	21.0	...	6	...
H34[C]	0.009–0.019	32.0	38.0	25.0	...	1	2
or	0.020–0.050	32.0	38.0	25.0	...	3	3
H24[C]	0.051–0.113	32.0	38.0	25.0	...	4	4
	0.114–1.000	32.0	38.0	25.0	...	5	...
H36[C]	0.006–0.007	35.0	41.0	28.0	...	...	...
or	0.008–0.019	35.0	41.0	28.0	...	1	6
H26[C]	0.020–0.031	35.0	41.0	28.0	...	2	6
	0.032–0.050	35.0	41.0	28.0	...	3	6
	0.051–0.162	35.0	41.0	28.0	...	4	8
H38[C]	0.006–0.007	38.0	...	31.0	...	...	...
or	0.008–0.019	38.0	...	31.0	...	1	...
H28[C]	0.020–0.031	38.0	...	31.0	...	2	...
	0.032–0.050	38.0	...	31.0	...	3	...
	0.051–0.128	38.0	...	31.0	...	4	...
H112	0.250–3.000	23.0	...	9.0	...	7	...
F[D]	0.250–3.000	...	...	...	...	...	...
		Alclad Alloy 3004					
O	0.006–0.007	21.0	28.0	8.0	...	...	...
	0.008–0.019	21.0	28.0	8.0	...	10	...
	0.020–0.031	21.0	28.0	8.0	...	14	...
	0.032–0.050	21.0	28.0	8.0	...	16	...
	0.051–0.249	21.0	28.0	8.0	...	18	...
	0.250–0.499	21.0	28.0	8.0	...	16	...
	0.500–3.000	22.0[E]	29.0[E]	8.5[E]	...	16	...

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
H32[C]	0.017–0.019	27.0	34.0	20.0	...	1	...
or	0.020–0.031	27.0	34.0	20.0	...	3	...
H22[C]	0.032–0.050	27.0	34.0	20.0	...	4	...
	0.051–0.113	27.0	34.0	20.0	...	5	...
	0.114–0.249	27.0	34.0	20.0	...	6	...
	0.250–0.499	27.0	34.0	20.0	...	6	...
	0.500–2.000	28.0[E]	35.0[E]	21.0[E]	...	6	...
H34[C]	0.009–0.019	31.0	37.0	24.0	...	1	...
or	0.020–0.050	31.0	37.0	24.0	...	3	...
H24[C]	0.051–0.113	31.0	37.0	24.0	...	4	...
	0.114–0.249	31.0	37.0	24.0	...	5	...
	0.250–0.499	31.0	37.0	24.0	...	5	...
	0.500–1.000	32.0[E]	38.0[E]	25.0[E]	...	5	...
H36[C]	0.006–0.007	34.0	40.0	27.0	...	...	...
or	0.008–0.019	34.0	40.0	27.0	...	1	...
H26[C]	0.020–0.031	34.0	40.0	27.0	...	2	...
	0.032–0.050	34.0	40.0	27.0	...	3	...
	0.051–0.162	34.0	40.0	27.0	...	4	...
H38	0.006–0.007	37.0	...	...	...	...	...
	0.008–0.019	37.0	...	...	...	1	...
	0.020–0.031	37.0	...	...	...	2	...
	0.032–0.050	37.0	...	...	...	3	...
	0.051–0.128	37.0	...	...	...	4	...
H112	0.250–0.499	22.0	...	8.5	...	7	...
	0.500–3.000	23.0[E]	...	9.0[E]	...	7	...
F[D]	0.250–3.000	...	...	...	...	...	...
		Alloy 3005					
O	0.006–0.007	17.0	24.0	6.5	...	10	...
	0.008–0.012	17.0	24.0	6.5	...	12	...
	0.013–0.019	17.0	24.0	6.5	...	14	...
	0.020–0.031	17.0	24.0	6.5	...	16	...
	0.032–0.050	17.0	24.0	6.5	...	18	...
	0.051–0.249	17.0	24.0	6.5	...	20	...
H12	0.017–0.019	20.0	27.0	17.0	...	1	...
	0.020–0.050	20.0	27.0	17.0	...	2	...
	0.051–0.113	20.0	27.0	17.0	...	3	...
	0.114–0.161	20.0	27.0	17.0	...	4	...
	0.162–0.249	20.0	27.0	17.0	...	5	...
H14	0.009–0.031	24.0	31.0	21.0	...	1	...
	0.032–0.050	24.0	31.0	21.0	...	2	...
	0.051–0.113	24.0	31.0	21.0	...	3	...
	0.114–0.249	24.0	31.0	21.0	...	4	...
H16	0.006–0.031	28.0	35.0	25.0	...	1	...
	0.032–0.113	28.0	35.0	25.0	...	2	...
	0.114–0.162	28.0	35.0	25.0	...	3	...
H18	0.006–0.031	32.0	...	29.0	...	1	...
	0.032–0.128	32.0	...	29.0	...	2	...
H19	0.006–0.012	34.0	...	...	...	...	...
	0.013–0.063	34.0	...	...	...	1	...
H25	0.016–0.019	26.0	34.0	22.0	...	1	...
	0.020–0.031	26.0	34.0	22.0	...	2	...
	0.032–0.050	26.0	34.0	22.0	...	3	...
	0.051–0.080	26.0	34.0	22.0	...	4	...
H27	0.016–0.019	29.5	37.5	25.5	...	1	...
	0.020–0.031	29.5	37.5	25.5	...	2	...
	0.032–0.050	29.5	37.5	25.5	...	3	...
	0.051–0.080	29.5	37.5	25.5	...	4	...

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
H28	0.016–0.019	31.0	...	27.0	...	1	...
	0.020–0.031	31.0	...	27.0	...	2	...
	0.032–0.050	31.0	...	27.0	...	3	...
	0.051–0.080	31.0	...	27.0	...	4	...
H29	0.025–0.031	33.0	...	28.0	...	1	...
	0.032–0.050	33.0	...	28.0	...	2	...
	0.051–0.071	33.0	...	28.0	...	3	...
			Alloy 3105				
O	0.013–0.019	14.0	21.0	5.0	...	16	...
	0.020–0.031	14.0	21.0	5.0	...	18	...
	0.032–0.080	14.0	21.0	5.0	...	20	...
H12	0.017–0.019	19.0	26.0	15.0	...	1	...
	0.020–0.031	19.0	26.0	15.0	...	1	...
	0.032–0.050	19.0	26.0	15.0	...	2	...
	0.051–0.080	19.0	26.0	15.0	...	3	...
H14	0.013–0.019	22.0	29.0	18.0	...	1	...
	0.020–0.031	22.0	29.0	18.0	...	1	...
	0.032–0.050	22.0	29.0	18.0	...	2	...
	0.051–0.080	22.0	29.0	18.0	...	2	...
H16	0.013–0.031	25.0	32.0	21.0	...	1	...
	0.032–0.050	25.0	32.0	21.0	...	2	...
	0.051–0.080	25.0	32.0	21.0	...	2	...
H18	0.013–0.031	28.0	...	24.0	...	1	...
	0.032–0.050	28.0	...	24.0	...	1	...
	0.051–0.080	28.0	...	24.0	...	2	...
H25	0.013–0.019	23.0	...	19.0	...	2	...
	0.020–0.031	23.0	...	19.0	...	3	...
	0.032–0.050	23.0	...	19.0	...	4	...
	0.051–0.080	23.0	...	19.0	...	6	...
			Alloy 5005				
O	0.006–0.007	15.0	21.0	5.0	...	12	...
	0.008–0.012	15.0	21.0	5.0	...	14	...
	0.013–0.019	15.0	21.0	5.0	...	16	...
	0.020–0.031	15.0	21.0	5.0	...	18	...
	0.032–0.050	15.0	21.0	5.0	...	20	...
	0.051–0.113	15.0	21.0	5.0	...	21	...
	0.114–0.249	15.0	21.0	5.0	...	22	...
	0.250–3.000	15.0	21.0	5.0	...	22	...
H12	0.017–0.019	18.0	24.0	14.0	...	2	...
	0.020–0.031	18.0	24.0	14.0	...	3	...
	0.032–0.050	18.0	24.0	14.0	...	4	...
	0.051–0.113	18.0	24.0	14.0	...	6	...
	0.114–0.161	18.0	24.0	14.0	...	7	...
	0.162–0.249	18.0	24.0	14.0	...	8	...
	0.250–0.499	18.0	24.0	14.0	...	9	...
	0.500–2.000	18.0	24.0	14.0	...	10	...
H14	0.009–0.031	21.0	27.0	17.0	...	1	...
	0.032–0.050	21.0	27.0	17.0	...	2	...
	0.051–0.113	21.0	27.0	17.0	...	3	...
	0.114–0.161	21.0	27.0	17.0	...	5	...
	0.162–0.249	21.0	27.0	17.0	...	6	...
	0.250–0.499	21.0	27.0	17.0	...	8	...
	0.500–1.000	21.0	27.0	17.0	...	10	...
H16	0.006–0.031	24.0	30.0	20.0	...	1	...
	0.032–0.050	24.0	30.0	20.0	...	2	...
	0.051–0.162	24.0	30.0	20.0	...	3	...
H18	0.006–0.031	27.0	...	...	...	1	...
	0.032–0.050	27.0	...	...	...	2	...
	0.051–0.128	27.0	...	...	...	3	...

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
H32[C]	0.017–0.019	17.0	23.0	12.0	...	3	...
or	0.020–0.031	17.0	23.0	12.0	...	4	...
H22[C]	0.032–0.050	17.0	23.0	12.0	...	5	...
	0.051–0.113	17.0	23.0	12.0	...	7	...
	0.114–0.161	17.0	23.0	12.0	...	8	...
	0.162–0.249	17.0	23.0	12.0	...	9	...
	0.250–2.000	17.0	23.0	12.0	...	10	...
H34[C]	0.009–0.012	20.0	26.0	15.0	...	2	...
or	0.013–0.031	20.0	26.0	15.0	...	3	...
H24[C]	0.032–0.050	20.0	26.0	15.0	...	4	...
	0.051–0.113	20.0	26.0	15.0	...	5	...
	0.114–0.161	20.0	26.0	15.0	...	6	...
	0.162–0.249	20.0	26.0	15.0	...	7	...
	0.250–0.499	20.0	26.0	15.0	...	8	...
	0.500–1.000	20.0	26.0	15.0	...	10	...
H36[C]	0.006–0.007	23.0	29.0	18.0	...	1	...
or	0.008–0.019	23.0	29.0	18.0	...	2	...
H26[C]	0.020–0.031	23.0	29.0	18.0	...	3	...
	0.032–0.162	23.0	29.0	18.0	...	4	...
H38	0.006–0.012	26.0	...	...	...	1	...
	0.013–0.019	26.0	...	...	...	2	...
	0.020–0.031	26.0	...	...	...	3	...
	0.032–0.128	26.0	...	...	...	4	...
H112	0.250–0.499	17.0	...	...	...	8	...
	0.500–2.000	15.0	...	...	...	12	...
	2.001–3.000	14.5	...	...	...	18	...
F[D]	0.250–3.000	...	...	...	...	...	...
		Alloy 5010					
O	0.010–0.070	15.0	21.0	5.0	...	3	...
H22	0.010–0.070	17.0	23.0	14.0	...	2	...
H24	0.010–0.070	20.0	26.0	17.0	...	1	...
H26	0.010–0.070	23.0	29.0	21.0	...	1	...
H28	0.010–0.070	26.0	...	...	...	...	...
		Alloy 5050					
O	0.006–0.007	18.0	24.0	6.0	...	...	0
	0.008–0.019	18.0	24.0	6.0	...	16	0
	0.020–0.031	18.0	24.0	6.0	...	18	0
	0.032–0.050	18.0	24.0	6.0	...	20	0
	0.051–0.113	18.0	24.0	6.0	...	20	0
	0.114–0.249	18.0	24.0	6.0	...	22	0
	0.250–3.000	18.0	24.0	6.0	...	20	2
H32[C]	0.017–0.050	22.0	28.0	16.0	...	4	1
or	0.051–0.249	22.0	28.0	16.0	...	6	2
H22[C]							
H34[C]	0.009–0.031	25.0	31.0	20.0	...	3	1
or	0.032–0.050	25.0	31.0	20.0	...	4	1
H24[C]	0.051–0.249	25.0	31.0	20.0	...	5	3
H36[C]	0.006–0.019	27.0	33.0	22.0	...	2	3
or	0.020–0.050	27.0	33.0	22.0	...	3	3
H26[C]	0.051–0.162	27.0	33.0	22.0	...	4	4
H38	0.006–0.007	29.0	...	...	...	...	...
	0.008–0.031	29.0	...	...	...	2	...
	0.032–0.050	29.0	...	...	...	3	...
	0.051–0.128	29.0	...	...	...	4	...

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
H112	0.250–3.000	20.0	...	8.0	...	12	...
F[D]	0.250–3.000	...	...	...	...	...	...
			Alloy 5052				
O	0.008–0.007	25.0	31.0	9.5	...	...	0
	0.008–0.012	25.0	31.0	9.5	...	14	0
	0.013–0.019	25.0	31.0	9.5	...	15	0
	0.020–0.031	25.0	31.0	9.5	...	16	0
	0.032–0.050	25.0	31.0	9.5	...	18	0
	0.051–0.113	25.0	31.0	9.5	...	19	0
	0.114–0.249	25.0	31.0	9.5	...	20	0
	0.250–3.000	25.0	31.0	9.5	...	18	...
H32[C]	0.017–0.019	31.0	38.0	23.0	...	4	0
or	0.020–0.050	31.0	38.0	23.0	...	5	1
H22[C]	0.051–0.113	31.0	38.0	23.0	...	7	2
	0.114–0.249	31.0	38.0	23.0	...	9	3
	0.250–0.499	31.0	38.0	23.0	...	11	...
	0.500–2.000	31.0	38.0	23.0	...	12	...
H34[C]	0.009–0.019	34.0	41.0	26.0	...	3	1
or	0.020–0.050	34.0	41.0	26.0	...	4	2
H24[C]	0.051–0.113	34.0	41.0	26.0	...	6	3
	0.114–0.249	34.0	41.0	26.0	...	7	4
	0.250–1.000	34.0	41.0	26.0	...	10	...
H3[C]	0.006–0.007	37.0	44.0	29.0	...	2	4
or	0.008–0.031	37.0	44.0	29.0	...	3	4
H26[C]	0.032–0.162	37.0	44.0	29.0	...	4	5
H38[C]	0.006–0.007	39.0	...	32.0	...	2	...
or	0.008–0.031	39.0	...	32.0	...	3	...
H28[C]	0.032–0.128	39.0	...	32.0	...	4	...
H112	0.250–0.499	26.0	...	16.0	...	7	...
	0.500–2.000	25.0	...	9.5	...	12	...
	2.001–3.000	25.0	...	9.5	...	16	...
F[D]	0.250–3.000	...	...	...	...	...	...
			Alloy 5083				
O	0.051–1.500	40.0	51.0	18.0	29.0	16	...
	1.501–3.000	39.0	50.0	17.0	29.0	16	...
	3.001–4.000	38.0	...	16.0	...	16	...
	4.001–5.000	38.0	...	16.0	...	14	...
	5.001–7.000	37.0	...	15.0	...	14	...
	7.001–8.000	36.0	...	14.0	...	12	...
H321	0.188–1.500	44.0	56.0	31.0	43.0	12	...
	1.501–3.000	41.0	56.0	29.0	43.0	12	...
H112	0.250–1.500	40.0	...	18.0	...	12	...
	1.501–3.000	39.0	...	17.0	...	12	...
H116[F]	0.063–0.499	44.0	...	31.0	...	10	...
	0.500–1.250	44.0	...	31.0	...	12	...
	1.251–1.500	44.0	...	31.0	...	12	...
	1.501–3.000	41.0	...	29.0	...	12	...
F[D]	0.250–8.000	...	...	...	...	...	...
			Alloy 5086				
O	0.020–0.050	35.0	44.0	14.0	...	15	...
	0.051–0.249	35.0	44.0	14.0	...	18	...
	0.250–2.000	35.0	44.0	14.0	...	16	...
H32[C]	0.020–0.050	40.0	47.0	28.0	...	6	...
or	0.051–0.249	40.0	47.0	28.0	...	8	...
H22[C]	0.250–2.000	40.0	47.0	28.0	...	12	...

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
H34[C]	0.009–0.019	44.0	51.0	34.0	...	4	...
or	0.020–0.050	44.0	51.0	34.0	...	5	...
H24[C]	0.051–0.249	44.0	51.0	34.0	...	6	...
	0.250–1.000	44.0	51.0	34.0	...	10	
H36[C]	0.006–0.019	47.0	54.0	38.0	...	3	...
or	0.020–0.050	47.0	54.0	38.0	...	4	...
H26[C]	0.051–0.162	47.0	54.0	38.0	...	6	...
H38[C] or H28[C]	0.006–0.020	50.0	...	41.0	...	3	...
H112	0.188–0.499	36.0	...	18.0	...	8	...
	0.500–1.000	35.0	...	16.0	...	10	...
	1.001–2.000	35.0	...	14.0	...	14	...
	2.001–3.000	34.0	...	14.0	...	14	...
H116[F]	0.063–0.249	40.0	...	28.0	...	8	...
	0.250–0.499	40.0	...	28.0	...	10	...
	0.500–1.250	40.0	...	28.0	...	10	...
	1.251–2.000	40.0	...	28.0	...	10	...
F[D]	0.250–3.000	...	...	...	...	...	...
			Alloy 5154				
O	0.020–0.031	30.0	41.0	11.0	...	12	...
	0.032–0.050	30.0	41.0	11.0	...	14	...
	0.051–0.113	30.0	41.0	11.0	...	16	...
	0.114–3.000	30.0	41.0	11.0	...	18	...
H32[C]	0.020–0.050	36.0	43.0	26.0	...	5	...
or	0.051–0.249	36.0	43.0	26.0	...	8	...
H22[C]	0.250–2.000	36.0	43.0	26.0	...	12	...
H34[C]	0.009–0.050	39.0	46.0	29.0	...	4	...
or	0.051–0.161	39.0	46.0	29.0	...	6	...
H24[C]	0.162–0.249	39.0	46.0	29.0	...	7	...
	0.250–1.000	39.0	46.0	29.0	...	10	...
H36[C]	0.006–0.050	42.0	49.0	32.0	...	3	...
or	0.051–0.113	42.0	49.0	32.0	...	4	...
H26[C]	0.114–0.162	42.0	49.0	32.0	...	5	...
H38[C]	0.006–0.050	45.0	...	35.0	...	3	...
or	0.051–0.113	45.0	...	35.0	...	4	...
H28[C]	0.114–0.128	45.0	...	35.0	...	5	...
H112	0.250–0.499	32.0	...	18.0	...	8	...
	0.500–2.000	30.0	...	11.0	...	11	...
	2.001–3.000	30.0	...	11.0	...	15	...
F[D]	0.250–3.000	...	...	...	...	...	...
			Alloy 5252				
H24	0.030–0.090	30.0	38.0	...	...	10	...
H25	0.030–0.090	31.0	39.0	...	...	9	...
H28	0.030–0.090	38.0	...	...	...	3	...
			Alloy 5254				
O	0.051–0.113	30.0	41.0	11.0	...	16	...
	0.114–3.000	30.0	41.0	11.0	...	18	...
H32[C] or H22[C]	0.051–0.249 0.250–2.000	36.0 36.0	43.0 43.0	26.0 26.0	... ...	8 12	... ...
H34[C]	0.051–0.161	39.0	46.0	29.0	...	6	...
or	0.162–0.249	39.0	46.0	29.0	...	7	...
H24[C]	0.250–1.000	39.0	46.0	29.0	...	10	...

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
H36[C] or H26[C]	0.051–0.113	42.0	49.0	32.0	...	4	...
	0.114–0.162	42.0	49.0	32.0	...	5	...
H38[C] or H28[C]	0.051–0.113	45.0	...	35.0	...	4	...
	0.114–0.128	45.0	...	35.0	...	5	...
H112	0.250–0.499	32.0	...	18.0	...	8	...
	0.500–2.000	30.0	...	11.0	...	11	...
	2.001–3.000	30.0	...	11.0	...	15	...
F[D]	0.250–3.000	...	...	...	...	...	...
		Alloy 5454					
O	0.020–0.031	31.0	41.0	12.0	...	12	...
	0.032–0.050	31.0	41.0	12.0	...	14	...
	0.051–0.113	31.0	41.0	12.0	...	16	...
	0.114–3.000	31.0	41.0	12.0	...	18	...
H32[C] or H22[C]	0.020–0.050	36.0	44.0	26.0	...	5	...
	0.051–0.249	36.0	44.0	26.0	...	8	...
	0.250–2.000	36.0	44.0	26.0	...	12	...
H34[C] or H24[C]	0.020–0.050	39.0	47.0	29.0	...	4	...
	0.051–0.161	39.0	47.0	29.0	...	6	...
	0.162–0.249	39.0	47.0	29.0	...	7	...
	0.250–1.000	39.0	47.0	29.0	...	10	...
H112	0.250–0.499	32.0	...	18.0	...	8	...
	0.500–2.000	31.0	...	12.0	...	11	...
	2.001–3.000	31.0	...	12.0	...	15	...
F[C]	0.250–3.000	...	...	...	...	...	...
		Alloy 5456					
O	0.051–1.500	42.0	53.0	19.0	30.0	16	...
	1.501–3.000	41.0	52.0	18.0	30.0	16	...
	3.001–5.000	40.0	...	17.0	...	14	...
	5.001–7.000	39.0	...	16.0	...	14	...
	7.001–8.000	38.0	...	15.0	...	12	...
H321	0.188–0.499	46.0	59.0	33.0	46.0	12	...
	0.500–1.500	44.0	56.0	31.0	44.0	12	...
	1.501–3.000	41.0	54.0	29.0	43.0	12	...
H112	0.250–1.500	42.0	...	19.0	...	12	...
	1.501–3.000	41.0	...	18.0	...	12	...
H116[F]	0.063–0.499	46.0	...	33.0	...	10	...
	0.500–1.250	46.0	...	33.0	...	12	...
	1.251–1.500	44.0	...	31.0	...	12	...
	1.501–3.000	41.0	...	29.0	...	12	...
	3.001–4.000	40.0	...	25.0	...	12	
F[C]	0.250–8.000	...	...	...	...	...	...
		Alloy 5457					
O	0.030–0.090	16.0	22.0	...	...	20	...
		Alloy 5652					
O	0.051–0.113	25.0	31.0	9.5	...	19	0
	0.114–0.249	25.0	31.0	9.5	...	20	0
	0.250–3.000	25.0	31.0	9.5	...	18	...
H32[D] or H22[D]	0.051–0.113	31.0	38.0	23.0	...	7	2
	0.114–0.249	31.0	38.0	23.0	...	9	3
	0.250–0.499	31.0	38.0	23.0	...	11	...
	0.500–2.000	31.0	38.0	23.0	...	12	...
H34[D]	0.051–0.113	34.0	41.0	26.0	...	6	3

TABLE 2 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
or	0.114–0.249	34.0	41.0	26.0	...	7	4
H24[D]	0.250–1.000	34.0	41.0	26.0	...	10	...
H112	0.250–0.499	28.0	...	16.0	...	7	...
	0.500–2.000	25.0	...	9.5	...	12	...
	2.001–3.000	25.0	...	9.5	...	16	...
F[C]	0.250–3.000	...	...	...	...	...	...
		Alloy 5657					
H241[G]	0.030–0.090	18.0	26.0	...	...	13	...
H25	0.030–0.090	20.0	28.0	...	...	8	...
H26	0.030–0.090	22.0	30.0	...	...	7	...
H28	0.030–0.090	25.0	...	...	...	5	...

[A] To determine conformance to this specification each value for tensile strength and for yield strength shall be rounded to the nearest 0.1 ksi and each value for elongation to the nearest 0.5 %, both in accordance with the rounding method of Practice E 29.

[B] The basis for establishment of mechanical property limits is shown in Annex A1.

[C] Material in either of these tempers (H32 or H22), (H34 or H24), (H36 or H26), (H38 or H28), (H12 or H22), (H14 or H24), (H16 or H26), (H18 or H28), may be supplied at the option of the supplier, unless one is specifically excluded by the contract or purchase order. When ordered as H2x tempers, the maximum tensile strength and minimum yield strength do not apply. When H2x tempers are supplied instead of ordered H1x or H3x tempers, the supplied H2x temper material shall meet the respective H1x or H3x temper tensile property limits.

[D] Tests of F temper plate for tensile properties are not required.

[E] The tension test specimen from plate 0.500 in. and thicker is machined from the core and does not include the cladding alloy.

[F] The -H116 temper designation now also applies to products previously designated -H117.

TABLE 3 Tensile Property Limits for Heat-Treatable Alloys[A,B]

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
		Alloy 2014					
O	0.020–0.124	...	32.0	...	16.0	16	0
	0.125–0.249	...	32.0	...	16.0	16	1
	0.250–0.499	...	32.0	...	16.0	16	2
T3	0.020–0.039	59.0	...	35.0	...	14	3
	0.040–0.124	59.0	...	36.0	...	14	3
	0.125–0.249	59.0	...	36.0	...	14	4
T4[C]	0.020–0.124	59.0	...	35.0	...	14	3
	0.125–0.249	59.0	...	35.0	...	14	4
T42[D]	0.020–0.124	58.0	...	34.0	...	14	3
	0.125–0.249	58.0	...	34.0	...	14	4
	0.250–0.499	58.0	...	34.0	...	14	5
	0.500–1.000	58.0	...	34.0	...	14	...
T451[E]	0.250–1.000	58.0	...	36.0	...	14	...
	1.001–2.000	58.0	...	36.0	...	12	...
	2.001–3.000	57.0	...	36.0	...	8	...
T6, T62[D]	0.020–0.039	64.0	...	57.0	...	6	4
	0.040–0.050	66.0	...	58.0	...	7	5
	0.051–0.124	66.0	...	58.0	...	7	6
	0.125–0.249	66.0	...	58.0	...	7	8
T62[D], T651[E]	0.250–0.499	67.0	...	59.0	...	7	10
	0.500–1.000	67.0	...	59.0	...	6	...
	1.001–2.000	67.0	...	59.0	...	4	...
	2.001–2.500	65.0	...	58.0	...	2	...
	2.501–3.000	63.0	...	57.0	...	2	...
	3.001–4.000	59.0	...	55.0	...	1	...
F[F]	0.250–1.000	...	...	...	...	...	...

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
			Alclad Alloy 2014				
O	0.020–0.499	...	30.0	...	14.0	16	...
	0.500–1.000	...	32.0[G]	...	...	10	...
T3	0.020–0.039	54.0	...	33.0	...	14	...
	0.040–0.124	55.0	...	34.0	...	14	...
	0.125–0.249	57.0	...	35.0	...	15	...
T4[C]	0.020–0.124	54.0	...	31.0	...	14	...
	0.125–0.249	55.0	...	32.0	...	14	...
	0.040–0.249	57.0	...	34.0	...	15	...
T42[D]	0.020–0.124	54.0	...	31.0	...	14	...
	0.125–0.249	55.0	...	32.0	...	14	...
	0.250–0.499	57.0	...	34.0	...	15	...
	0.500–1.000	58.0[G]	...	34.0[G]	...	14	...
T451[E]	0.250–0.499	57.0	...	36.0	...	15	...
	0.500–1.000	58.0[G]	...	36.0[G]	...	14	...
	1.001–2.000	58.0[G]	...	36.0[G]	...	12	...
	2.001–3.000	57.0[G]	...	36.0[G]	...	8	...
T6, T62[D]	0.020–0.039	62.0	...	54.0	...	7	...
	0.040–0.050	63.0	...	55.0	...	7	...
	0.051–0.124	64.0	...	57.0	...	8	...
	0.125–0.249	...	...	...	...	...	...
T62[D], T651[E]	0.250–0.499	64.0	...	57.0	...	8	...
	0.500–1.000	67.0[G]	...	59.0[G]	...	6	...
	1.001–2.000	67.0[G]	...	59.0[G]	...	4	...
	2.001–2.500	65.0[G]	...	58.0[G]	...	2	...
	2.501–3.000	63.0[G]	...	57.0[G]	...	2	...
	3.001–4.000	59.0[G]	...	55.0[G]	...	1	...
F[F]	0.250–1.000	...	...	...	...	...	...
			Alloy 2024				
O	0.010–0.032	...	32.0	...	14.0	12	0
	0.033–0.063	...	32.0	...	14.0	12	1
	0.064–0.128	...	32.0	...	14.0	12	4
	0.129–0.499	...	32.0	...	14.0	12	6
T3	0.008–0.009	63.0	...	42.0	...	10	4
	0.010–0.020	63.0	...	42.0	...	12	4
	0.021–0.051	63.0	...	42.0	...	15	5
	0.052–0.128	63.0	...	42.0	...	15	6
	0.129–0.249	64.0	...	42.0	...	15	8
T351[E]	0.250–0.499	64.0	...	42.0	...	12	...
	0.500–1.000	63.0	...	42.0	...	8	...
	1.001–1.500	62.0	...	42.0	...	7	...
	1.501–2.000	62.0	...	42.0	...	6	...
	2.001–3.000	60.0	...	42.0	...	4	...
	3.001–4.000	57.0	...	41.0	...	4	
T361[H]	0.020–0.051	67.0	...	50.0	...	8	4
	0.052–0.062	67.0	...	50.0	...	8	8
	0.063–0.249	68.0	...	51.0	...	9	8
	0.250–0.499	66.0	...	49.0	...	9	...
	0.500	66.0	...	49.0	...	10	...
T4[C]	0.010–0.020	62.0	...	40.0	...	12	4
	0.021–0.051	62.0	...	40.0	...	15	5
	0.052–0.128	62.0	...	40.0	...	15	6
	0.129–0.249	62.0	...	40.0	...	15	8
T42[D]	0.010–0.020	62.0	...	38.0	...	12	4
	0.021–0.051	62.0	...	38.0	...	15	5
	0.052–0.128	62.0	...	38.0	...	15	6
	0.129–0.249	62.0	...	38.0	...	15	8

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
	0.250–0.499	62.0	...	38.0	...	12	10
	0.500–1.000	61.0	...	38.0	...	8	...
	1.001–1.500	60.0	...	38.0	...	7	...
	1.501–2.000	60.0	...	38.0	...	6	...
	2.001–3.000	58.0	...	38.0	...	4	...
T62[D]	0.010–0.499	64.0	...	50.0	...	5	...
	0.500–2.000	63.0	...	50.0	...	5	...
T72[DI]	0.010–0.249	60.0	...	46.0	...	5	...
T81	0.010–0.249	67.0	...	58.0	...	5	...
T851[E]	0.250–0.499	67.0	...	58.0	...	5	...
	0.500–1.000	66.0	...	58.0	...	5	...
	1.001–1.499	66.0	...	57.0	...	5	...
T861[H]	0.020–0.062	70.0	...	62.0	...	3	...
	0.063–0.249	71.0	...	66.0	...	4	...
	0.250–0.499	70.0	...	64.0	...	4	...
	0.500	70.0	...	64.0	...	4	...
F[F]	0.250–3.000	...	...	...	...	...	...
		Alclad Alloy 2024					
O	0.008–0.009	...	30.0	...	14.0	10	0
	0.010–0.032	...	30.0	...	14.0	12	0
	0.033–0.062	...	30.0	...	14.0	12	1
	0.063–0.249	...	32.0	...	14.0	12	2
	0.250–0.499	...	32.0	...	14.0	12	3
	0.500–1.750	...	32.0[G]	...	...	12	...
T3	0.008–0.009	58.0	...	39.0	...	10	4
	0.010–0.020	59.0	...	39.0	...	12	4
	0.021–0.040	59.0	...	39.0	...	15	4
	0.041–0.062	59.0	...	39.0	...	15	5
	0.063–0.128	61.0	...	40.0	...	15	5
	0.129–0.249	62.0	...	40.0	...	15	8
T351[E]	0.250–0.499	62.0	...	40.0	...	12	...
	0.500–1.000	63.0[G]	...	42.0[G]	...	8	...
	1.001–1.500	62.0[G]	...	42.0[G]	...	7	...
	1.501–2.000	62.0[G]	...	42.0[G]	...	6	...
	2.001–3.000	60.0[G]	...	42.0[G]	...	4	...
	3.001–4.000	57.0[G]	...	41.0[G]	...	4	...
T361[H]	0.020–0.062	61.0	...	47.0	...	8	4
	0.063–0.187	64.0	...	48.0	...	9	6
	0.188–0.249	64.0	...	48.0	...	9	8
	0.250–0.499	64.0	...	48.0	...	9	...
	0.500	66.0[G]	...	49.0[G]	...	10	...
T4[C]	0.010–0.020	58.0	...	36.0	...	12	4
	0.021–0.040	58.0	...	36.0	...	15	4
	0.041–0.062	58.0	...	36.0	...	15	5
	0.063–0.128	61.0	...	38.0	...	15	5
T42[D]	0.008–0.009	55.0	...	34.0	...	10	4
	0.010–0.020	57.0	...	34.0	...	12	4
	0.021–0.040	57.0	...	34.0	...	15	4
	0.041–0.062	57.0	...	34.0	...	15	5
	0.063–0.128	60.0	...	36.0	...	15	5
	0.129–0.187	60.0	...	36.0	...	15	8
	0.188–0.249	60.0	...	36.0	...	15	8
	0.250–0.499	60.0	...	36.0	...	12	10
	0.500–1.000	61.0[G]	...	38.0[G]	...	8	...
	1.001–1.500	60.0[G]	...	38.0[G]	...	7	...
	1.501–2.000	60.0[G]	...	38.0[G]	...	6	...
	2.001–3.000	58.0[G]	...	38.0[G]	...	4	...
T62[D]	0.010–0.062	60.0	...	47.0	...	5	...
	0.063–0.499	62.0	...	49.0	...	5	...

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
T72[D,I]	0.010–0.062	56.0	...	43.0	...	5	...
	0.063–0.249	58.0	...	45.0	...	5	...
T81	0.010–0.062	62.0	...	54.0	...	5	...
	0.063–0.249	65.0	...	56.0	...	5	...
T851[E]	0.250–0.499	65.0	...	56.0	...	5	...
	0.500–1.000	66.0[G]	...	58.0[G]	...	5	...
T861[H]	0.020–0.062	64.0	...	58.0	...	3	...
	0.063–0.187	69.0	...	64.0	...	4	...
	0.188–0.249	69.0	...	64.0	...	4	...
	0.250–0.499	68.0	...	62.0	...	4	...
	0.500	70.0[G]	...	64.0[G]	...	4	...
F[F]	0.250–3.000	...	...	...	...	...	...
		1½ % Alclad Alloy 2024					
O	0.188–0.499	...	32.0	...	14.0	12	...
	0.500–1.750	...	32.0[G]	...	...	12	...
T3	0.188–0.249	63.0	...	41.0	...	15	...
T361	0.188–0.249	65.0	...	49.0	...	9	...
	0.250–0.499	65.0	...	48.0	...	9	...
	0.500	66.0[G]	...	49.0[G]	...	10	...
T351[E]	0.250–0.499	63.0	...	41.0	...	12	...
	0.500–1.000	63.0[G]	...	42.0[G]	...	8	...
	1.001–1.500	62.0[G]	...	42.0[G]	...	7	...
	1.501–2.000	62.0[G]	...	42.0[G]	...	6	...
	2.001–3.000	60.0[G]	...	42.0[G]	...	4	...
	3.001–4.000	57.0[G]	...	41.0[G]	...	4	...
T42[D]	0.188–0.249	61.0	...	37.0	...	15	...
	0.250–0.499	61.0	...	37.0	...	12	...
	0.500–1.000	61.0[G]	...	38.0[G]	...	8	...
	1.001–1.500	60.0[G]	...	38.0[G]	...	7	...
	1.501–2.000	60.0[G]	...	38.0[G]	...	6	...
	2.001–3.000	58.0[G]	...	38.0[G]	...	4	...
T62[D]	0.188–0.499	62.0	...	49.0	...	5	...
T72[D,I]	0.188–0.249	59.0	...	45.0	...	5	...
T81	0.188–0.249	66.0	...	57.0	...	5	...
T851[E]	0.250–0.499	66.0	...	57.0	...	5	...
	0.500–1.000	66.0[G]	...	58.0[G]	...	5	...
T861	0.188–0.249	70.0	...	65.0	...	4	...
	0.250–0.499	69.0	...	63.0	...	4	...
	0.500	70.0[G]	...	64.0[G]	...	4	...
F[F]	0.250–3.000	...	...	...	...	...	...
		Alclad One-Side Alloy 2024					
O	0.008–0.009	...	31.0	...	14.0	10	...
	0.010–0.062	...	31.0	...	14.0	12	...
	0.063–0.499	...	32.0	...	14.0	12	...
T3	0.010–0.020	61.0	...	40.0	...	12	...
	0.021–0.062	61.0	...	40.0	...	15	...
	0.063–0.128	62.0	...	41.0	...	15	...
	0.129–0.249	63.0	...	41.0	...	15	...
T351[E]	0.250–0.499	63.0	...	41.0	...	12	...
T361	0.020–0.062	64.0	...	48.0	...	8	...
	0.063–0.249	66.0	...	49.0	...	9	...
	0.250–0.499	65.0	...	48.0	...	9	...

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
T42[D]	0.010–0.020	59.0	...	35.0	...	12	...
	0.021–0.062	59.0	...	36.0	...	15	...
	0.063–0.249	61.0	...	37.0	...	15	...
	0.250–0.499	61.0	...	37.0	...	12	...
T62[D]	0.010–0.062	62.0	...	48.0	...	5	...
	0.063–0.249	63.0	...	49.0	...	5	...
T72[DI]	0.010–0.062	58.0	...	44.0	...	5	...
	0.063–0.499	59.0	...	45.0	...	5	...
T81	0.010–0.062	64.0	...	56.0	...	5	...
	0.063–0.249	66.0	...	57.0	...	5	...
T851[E]	0.250–0.499	66.0	...	57.0	...	5	...
T861	0.020–0.062	67.0	...	60.0	...	3	...
	0.063–0.249	70.0	...	65.0	...	4	...
	0.250–0.499	69.0	...	63.0	...	4	...
F[F]	0.250–0.499	...	...	...	...	...	...
		1½ % Alclad One-Side Alloy 2024					
O	0.188–0.499	...	32.0	...	14.0	12	...
T3	0.188–0.249	63.0	...	41.0	...	15	...
T351[E]	0.250–0.499	63.0	...	41.0	...	12	...
T361	0.188–0.249	66.0	...	49.0	...	9	...
	0.250–0.499	65.0	...	48.0	...	9	...
T42[D]	0.188–0.249	61.0	...	37.0	...	15	...
	0.250–0.499	61.0	...	37.0	...	12	...
T62[D]	0.188–0.499	63.0	...	49.0	...	5	...
T72[DI]	0.188–0.249	59.0	...	45.0	...	5	...
T81	0.188–0.249	66.0	...	57.0	...	5	...
T851[E]	0.250–0.499	66.0	...	57.0	...	5	...
T861	0.188–0.249	70.0	...	65.0	...	4	...
	0.250–0.499	69.0	...	63.0	...	4	...
F[F]	0.250–0.499	...	...	...	...	...	...

Temper	Specified Thickness, in.	Axis of Test Specimen	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
			min	max	min	max		
			Alloy 2124					
T851[E]	1.000–2.000[J]	Longitudinal	66.0	...	57.0	...	6	...
		Long Transverse	66.0	...	57.0	...	5	...
		Short Transverse	64.0	...	55.0	...	1.5	...
	2.001–3.000	Longitudinal	65.0	...	57.0	...	5	...
		Long Transverse	65.0	...	57.0	...	4	...
		Short Transverse	63.0	...	55.0	...	1.5	...
	3.001–4.000	Longitudinal	65.0	...	56.0	...	5	...
		Long Transverse	65.0	...	56.0	...	4	...
		Short Transverse	62.0	...	54.0	...	1.5	...
	4.001–5.000	Longitudinal	64.0	...	55.0	...	5	...
		Long Transverse	64.0	...	55.0	...	4	...
		Short Transverse	61.0	...	53.0	...	1.5	...
	5.001–6.000	Longitudinal	63.0	...	54.0	...	5	...
		Long Transverse	63.0	...	54.0	...	4	...
		Short Transverse	58.0	...	51.0	...	1.5	...

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
			Alloy 2219				
O	0.020–0.250	...	32.0	...	16.0	12	4
	0.251–0.750	...	32.0	...	16.0	12	6
	0.751–1.000	...	32.0	...	16.0	12	8
	1.001–2.000	...	32.0	...	16.0	12	...
	0.020–0.039	46.0	...	29.0	...	8	...
T31[K] (flat sheet)	0.040–0.249	46.0	...	28.0	...	10	...
T351[E,K] plate (formerly T31 plate)	0.250–2.000	46.0	...	28.0	...	10	...
	2.001–3.000	44.0	...	28.0	...	10	...
	3.001–4.000	42.0	...	27.0	...	9	...
	4.001–5.000	40.0	...	26.0	...	9	...
	5.001–6.000	39.0	...	25.0	...	8	...
T37[K]	0.020–0.039	49.0	...	38.0	...	6	...
	0.040–2.500	49.0	...	37.0	...	6	...
	2.501–3.000	47.0	...	36.0	...	6	...
	3.001–4.000	45.0	...	35.0	...	5	...
	4.001–5.000	43.0	...	34.0	...	4	...
T62[D]	0.020–0.039	54.0	...	36.0	...	6	...
	0.040–0.249	54.0	...	36.0	...	7	...
	0.250–1.000	54.0	...	36.0	...	8	...
	1.001–2.000	54.0	...	36.0	...	7	...
T81 sheet	0.020–0.039	62.0	...	46.0	...	6	...
	0.040–0.249	62.0	...	46.0	...	7	...
T851[E] plate (formerly T81 plate)	0.250–1.000	62.0	...	46.0	...	8	...
	1.001–2.000	62.0	...	46.0	...	7	...
	2.001–3.000	62.0	...	45.0	...	6	...
	3.001–4.000	60.0	...	44.0	...	5	...
	4.001–5.000	59.0	...	43.0	...	5	...
	5.001–6.000	57.0	...	42.0	...	4	...
T87	0.020–0.039	64.0	...	52.0	...	5	...
	0.040–0.249	64.0	...	52.0	...	6	...
	0.250–1.000	64.0	...	51.0	...	7	...
	1.001–2.000	64.0	...	51.0	...	6	...
	2.001–3.000	64.0	...	51.0	...	6	...
	3.001–4.000	62.0	...	50.0	...	4	...
	4.001–5.000	61.0	...	49.0	...	3	...
F[F]	0.250–2.000	...	...	...	...	...	...
			Alclad Alloy 2219				
O	0.020–0.200	...	32.0[G]	...	16.0[G]	12	...
T31 (flat sheet)[K]	0.040–0.099	42.0	...	25.0	...	10	...
	0.100–0.249	44.0	...	26.0	...	10	...
T351[E,K] plate (formerly T31 plate)	0.250–0.499	44.0	...	26.0	...	10	...
T37[K]	0.040–0.099	45.0	...	34.0	...	6	...
	0.100–0.499	47.0	...	35.0	...	6	...
T62[D]	0.020–0.039	44.0	...	29.0	...	6	...
	0.040–0.099	49.0	...	32.0	...	7	...
	0.100–0.249	51.0	...	34.0	...	7	...
	0.250–0.499	51.0	...	34.0	...	8	...
	0.500–1.000	54.0[G]	...	36.0[G]	...	8	...
	1.001–2.000	54.0[G]	...	36.0[G]	...	7	...
T81 (flat sheet)	0.020–0.039	49.0	...	37.0	...	6	...
	0.040–0.099	55.0	...	41.0	...	7	...
	0.100–0.249	58.0	...	43.0	...	7	...

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
T851[E] plate (formerly T81 plate)	0.250–0.499	58.0	...	42.0	...	8	...
T87	0.040–0.099	57.0	...	46.0	...	6	...
	0.100–0.249	60.0	...	48.0	...	6	...
	0.250–0.499	60.0	...	48.0	...	7	...
F[F]	0.250–2.000	...	...	...	...	...	...
			Alloy 6061				
O	0.006–0.007	...	22.0	...	12.0	10	0
	0.008–0.009	...	22.0	...	12.0	12	0
	0.010–0.020	...	22.0	...	12.0	14	0
	0.021–0.128	...	22.0	...	12.0	16	1
	0.129–0.249	...	22.0	...	12.0	18	2
	0.250–0.499	...	22.0	...	12.0	18	3
	0.500–1.000	...	22.0	...	...	18	...
	1.001–3.000	...	22.0	...	...	16	...
T4	0.006–0.007	30.0	...	16.0	...	10	2
	0.008–0.009	30.0	...	16.0	...	12	2
	0.010–0.020	30.0	...	16.0	...	14	2
	0.021–0.249	30.0	...	16.0	...	16	3
T451[E]	0.250–0.499	30.0	...	16.0	...	18	4
	0.500–1.000	30.0	...	16.0	...	18	...
	1.001–3.000	30.0	...	16.0	...	16	...
T42[D]	0.006–0.007	30.0	...	14.0	...	10	2
	0.008–0.009	30.0	...	14.0	...	12	2
	0.010–0.020	30.0	...	14.0	...	14	2
	0.021–0.249	30.0	...	14.0	...	16	3
	0.250–0.499	30.0	...	14.0	...	18	4
	0.500–1.000	30.0	...	14.0	...	18	...
	1.001–3.000	30.0	...	14.0	...	16	...
T6, T62[D]	0.006–0.007	42.0	...	35.0	...	4	2
	0.008–0.009	42.0	...	35.0	...	6	2
	0.010–0.020	42.0	...	35.0	...	8	2
	0.021–0.036	42.0	...	35.0	...	10	3
	0.037–0.064	42.0	...	35.0	...	10	4
	0.065–0.128	42.0	...	35.0	...	10	5
	0.129–0.249	42.0	...	35.0	...	10	6
T62[D], T651[E]	0.250–0.499	42.0	...	35.0	...	10	7
	0.500–1.000	42.0	...	35.0	...	9	...
	1.001–2.000	42.0	...	35.0	...	8	...
	2.001–4.000	42.0	...	35.0	...	6	...
	4.001–6.000[L]	40.0	...	35.0	...	6	...
F[F]	0.250–3.000	...	...	...	...	...	...
			Alclad Alloy 6061				
O	0.010–0.020	...	20.0	...	12.0	14	...
	0.021–0.128	...	20.0	...	12.0	16	...
	0.129–0.499	...	20.0	...	12.0	18	...
	0.500–1.000	...	22.0[G]	...	...	18	...
	1.001–3.000	...	22.0[G]	...	...	16	...
T4	0.010–0.020	27.0	...	14.0	...	14	...
	0.021–0.249	27.0	...	14.0	...	16	...
T451[E]	0.250–0.499	27.0	...	14.0	...	18	...
	0.500–1.000	30.0[G]	...	16.0[G]	...	18	...
	1.001–3.000	30.0[G]	...	16.0[G]	...	16	...
T42[D]	0.010–0.020	27.0	...	12.0	...	14	...
	0.021–0.249	27.0	...	12.0	...	16	...
	0.250–0.499	27.0	...	12.0	...	18	...
	0.500–1.000	30.0[G]	...	14.0[G]	...	18	...

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
	1.001–3.000	30.0[G]	...	14.0[G]	...	16	...
T6, T62[D]	0.010–0.020	38.0	...	32.0	...	8	...
	0.021–0.249	38.0	...	32.0	...	10	...
T62[D], T651[E]	0.250–0.499	38.0	...	32.0	...	10	...
	0.500–1.000	42.0[G]	...	35.0[G]	...	9	...
	1.001–2.000	42.0[G]	...	35.0[G]	...	8	...
	2.001–4.000	42.0[G]	...	35.0[G]	...	6	...
	4.001–5.000	40.0[G]	...	35.0[G]	...	6	...
F[D]	0.250–3.000	...	...	...	...	...	...
		Alloy 7075					
O	0.015–0.020	...	40.0	...	21.0	10	1
	0.021–0.062	...	40.0	...	21.0	10	2
	0.063–0.091	...	40.0	...	21.0	10	3
	0.092–0.125	...	40.0	...	21.0	10	4
	0.126–0.249	...	40.0	...	21.0	10	5
	0.250–0.499	...	40.0	...	21.0	10	6
	0.500–2.000	...	40.0	...	...	10	...
T6, T62[D]	0.008–0.011	74.0	...	63.0	...	5	7
	0.012–0.020	76.0	...	67.0	...	7	7
	0.021–0.039	76.0	...	67.0	...	7	8
	0.040–0.062	78.0	...	68.0	...	8	8
	0.063–0.091	78.0	...	68.0	...	8	9
	0.092–0.125	78.0	...	68.0	...	8	10
	0.126–0.249	78.0	...	69.0	...	8	11
T62[D], T651[E]	0.250–0.499	78.0	...	67.0	...	9	14
	0.500–1.000	78.0	...	68.0	...	7	...
	1.001–2.000	77.0	...	67.0	...	6	...
	2.001–2.500	76.0	...	64.0	...	5	...
	2.501–3.000	72.0	...	61.0	...	5	...
	3.001–3.500	71.0	...	58.0	...	5	...
	3.501–4.000	67.0	...	54.0	...	3	...
T73 sheet	0.040–0.249	67.0	...	56.0	...	8	...
T7351[E] plate	0.250–1.000	69.0	...	57.0	...	7	...
	1.001–2.000	69.0	...	57.0	...	6	...
	2.001–2.500	66.0	...	52.0	...	6	...
	2.501–3.000	64.0	...	49.0	...	6	...
	3.001–4.000	61.0	...	48.0	...	6	...
T76 sheet	0.063–0.124	73.0	...	62.0	...	8	...
	0.125–0.249	73.0	...	62.0	...	8	...
T7651 plate[E]	0.250–0.499	72.0	...	61.0	...	8	...
	0.500–1.000	71.0	...	60.0	...	6	...
	1.001–2.000	71.0	...	60.0	...	5	...
F[F]	0.250–4.000	...	...	...	...	...	...
		Alclad Alloy 7075					
O	0.008–0.014	...	36.0	...	20.0	9	1
	0.015–0.032	...	36.0	...	20.0	10	1
	0.033–0.062	...	36.0	...	20.0	10	2
	0.063–0.125	...	36.0	...	20.0	10	3
	0.126–0.187	...	36.0	...	20.0	10	4
	0.188–0.249	...	39.0	...	21.0	10	4
	0.250–0.499	...	39.0	...	21.0	10	6
	0.500–1.000	...	40.0[G]	...	...	10	...
T6, T62[D]	0.008–0.011	68.0	...	58.0	...	5	6
	0.012–0.020	70.0	...	60.0	...	7	6
	0.021–0.039	70.0	...	60.0	...	7	7
	0.040–0.062	72.0	...	62.0	...	8	7
	0.063–0.091	73.0	...	63.0	...	8	8
	0.092–0.125	73.0	...	63.0	...	8	9
	0.126–0.187	73.0	...	63.0	...	8	10

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
	0.188–0.249	75.0	...	64.0	...	8	10
T62[D], T651[E]	0.250–0.499	75.0	...	65.0	...	9	12
	0.500–1.000	78.0[G]	...	68.0[G]	...	7	...
	1.001–2.000	77.0[G]	...	67.0[G]	...	6	...
	2.001–2.500	76.0[G]	...	64.0[G]	...	5	...
	2.501–3.000	72.0[G]	...	61.0[G]	...	5	...
	3.001–3.500	71.0[G]	...	58.0[G]	...	5	...
	3.501–4.000	67.0[G]	...	54.0[G]	...	3	...
T76 sheet	0.040–0.062	67.0	...	56.0	...	8	...
	0.063–0.124	68.0	...	57.0	...	8	...
	0.125–0.187	68.0	...	57.0	...	8	...
	0.188–0.249	70.0	...	59.0	...	8	...
T7651[E] plate	0.250–0.499	69.0	...	58.0	...	8	...
	0.500–1.000	71.0[G]	...	60.0[G]	...	6	...
F[F]	0.250–4.000	...	...	...	...	...	...
		Alclad One Side Alloy 7075					
O	0.015–0.032	...	38.0	...	21.0	10	1
	0.033–0.062	...	38.0	...	21.0	10	2
	0.063–0.091	...	39.0	...	21.0	10	3
	0.092–0.125	...	39.0	...	21.0	10	4
	0.126–0.187	...	39.0	...	21.0	10	5
	0.188–0.249	...	39.0	...	21.0	10	5
	0.250–0.499	...	39.0	...	21.0	10	6
	0.500–1.000	...	40.0[G]	...	...	10	...
T6, T62[D]	0.008–0.011	71.0	...	60.0	...	5	...
	0.012–0.014	74.0	...	64.0	...	8	...
	0.015–0.032	74.0	...	64.0	...	8	7
	0.033–0.039	74.0	...	64.0	...	8	8
	0.040–0.062	75.0	...	65.0	...	9	8
	0.063–0.091	76.0	...	66.0	...	9	9
	0.092–0.125	76.0	...	66.0	...	9	10
	0.126–0.187	77.0	...	67.0	...	9	11
	0.188–0.249	78.0	...	67.0	...	9	11
T62[D], T651[E]	0.250–0.499	76.0	...	66.0	...	9	13
	0.500–1.000	78.0[G]	...	68.0[G]	...	7	...
	1.001–2.000	77.0[G]	...	67.0[G]	...	6	...
F[F]	0.250–2.000	...	...	...	...	...	...
		7008 Alclad Alloy 7075					
O	0.015–0.499	...	40.0	...	21.0	10	...
	0.500–2.000	...	40.0[G]	...	...	10	...
T6, T62[D]	0.015–0.039	73.0	...	63.0	...	7	...
	0.040–0.187	75.0	...	65.0	...	8	...
	0.188–0.249	76.0	...	66.0	...	8	...
T62[D], T651[E]	0.250–0.499	76.0	...	66.0	...	9	...
	0.500–1.000	78.0[G]	...	68.0[G]	...	7	...
	1.001–2.000	77.0[G]	...	67.0[G]	...	6	...
	2.001–2.500	76.0[G]	...	64.0[G]	...	5	...
	2.501–3.000	72.0[G]	...	61.0[G]	...	5	...
	3.001–3.500	71.0[G]	...	58.0[G]	...	5	...
	3.501–4.000	67.0[G]	...	54.0[G]		3	...
T76 sheet	0.040–0.062	70.0	...	59.0	...	8	...
	0.063–0.187	71.0	...	60.0	...	8	...
	0.188–0.249	72.0	...	61.0	...	8	...
T7651[E] plate	0.250–0.499	71.0	...	60.0	...	8	...
	0.500–1.000	71.0[G]	...	60.0[G]	...	6	...
F[F]	0.250–4.000	...	...	...	...	...	...
		7011 Alclad Alloy 7075					

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
O	0.015–0.020	...	40.0	...	21.0	10	1
	0.021–0.062	...	40.0	...	21.0	10	2
	0.063–0.091	...	40.0	...	21.0	10	3
	0.092–0.125	...	40.0	...	21.0	10	4
	0.126–0.249	...	40.0	...	21.0	10	5
	0.250–0.499	...	40.0	...	21.0	10	6
	0.500–2.000	...	40.0[G]	...	21.0[G]	10	...
T6, T62[D]	0.015–0.020	73.0	...	63.0	...	7	7
	0.021–0.039	73.0	...	63.0	...	7	8
	0.040–0.062	75.0	...	65.0	...	8	8
	0.063–0.091	75.0	...	65.0	...	8	9
	0.092–0.125	75.0	...	65.0	...	8	10
	0.126–0.187	75.0	...	65.0	...	8	11
	0.188–0.249	76.0	...	66.0	...	8	11
T62[D], T651	0.250–0.499	76.0	...	66.0	...	9	14
	0.500–1.000	78.0[G]	...	68.0[G]	...	7	...
	1.001–2.000	77.0[G]	...	67.0[G]	...	6	...
	2.001–2.500	76.0[G]	...	64.0[G]	...	5	...
	2.501–3.000	72.0[G]	...	61.0[G]	...	5	...
	3.001–3.500	71.0[G]	...	58.0[G]	...	5	...
	3.501–4.000	67.0[G]	...	54.0[G]	...	3	...
T76	0.040–0.062	70.0	...	59.0	...	8	8
	0.063–0.091	71.0	...	60.0	...	8	9
	0.092–0.125	71.0	...	60.0	...	8	10
	0.126–0.187	71.0	...	60.0	...	8	11
	0.188–0.249	72.0	...	61.0	...	8	11
T7651	0.250–0.499	71.0	...	60.0	...	8	...
	0.500–1.000	71.0[G]	...	60.0[G]	...	6	...
F	All	...	...	...	...	...	...
		Alloy 7178					
O	0.015–0.499	...	40.0	...	21.0	10	...
	0.500	...	40.0	...	...	10	...
T6, T62[D]	0.015–0.044	83.0	...	72.0	...	7	...
	0.045–0.249	84.0	...	73.0	...	8	...
T62[D],T651[E]	0.250–0.499	84.0	...	73.0	...	8	...
	0.500–1.000	84.0	...	73.0	...	6	...
	1.001–1.500	84.0	...	73.0	...	4	...
	1.501–2.000	80.0	...	70.0	...	3	...
T76	0.045–0.249	75.0	...	64.0	...	8	...
T7651[E]	0.250–0.499	74.0	...	63.0	...	8	...
	0.500–1.000	73.0	...	62.0	...	6	...
F[F]	0.250–2.000	...	...	...	...	...	...
		Alclad Alloy 7178					
O	0.015–0.062	...	36.0	...	20.0	10	...
	0.063–0.187	...	38.0	...	20.0	10	...
	0.188–0.499	...	40.0	...	21.0	10	...
	0.500	...	40.0[G]	...	...	10	...
T6, T62[D]	0.015–0.044	76.0	...	66.0	...	7	...
	0.045–0.062	78.0	...	68.0	...	8	...
	0.063–0.187	80.0	...	70.0	...	8	...
	0.188–0.249	82.0	...	71.0	...	8	...
T62[D], T651[E]	0.250–0.499	82.0	...	71.0	...	8	...
	0.500–1.000	84.0[G]	...	73.0[G]	...	6	...
	1.001–1.500	84.0[G]	...	73.0[G]	...	4	...
	1.501–2.000	80.0[G]	...	70.0[G]	...	3	...
T76	0.045–0.062	71.0	...	60.0	...	8	...
	0.063–0.187	71.0	...	60.0	...	8	...
	0.188–0.249	73.0	...	61.0	...	8	...
T7651[E]	0.250–0.499	72.0	...	60.0	...	8	...
	0.500–1.000	73.0[G]	...	62.0[G]	...	6	...

TABLE 3 *Continued*

Temper	Specified Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), ksi		Elongation in 2 in. or 4 × Diameter, min, %	Bend Diameter Factor, *N*
		min	max	min	max		
F[F]	0.250–2.000	...	...	...	...	...	...
		7011 Alclad Alloy 7178					
O	0.015–0.020	...	40.0	...	21.0	10	1
	0.021–0.062	...	40.0	...	21.0	10	2
	0.063–0.091	...	40.0	...	21.0	10	3
	0.092–0.125	...	40.0	...	21.0	10	4
	0.126–0.249	...	40.0	...	21.0	10	5
	0.250–0.499	...	40.0	...	21.0	10	6
	0.500–2.000	...	40.0[G]	...	...	10	...
T6, T62[D]	0.015–0.020	79.0	...	69.0	...	7	7
	0.021–0.044	79.0	...	69.0	...	7	8
	0.045–0.062	81.0	...	70.0	...	8	8
	0.063–0.091	82.0	...	71.0	...	8	9
	0.092–0.125	82.0	...	71.0	...	8	10
	0.126–0.187	82.0	...	71.0	...	8	11
	0.188–0.249	83.0	...	72.0	...	8	14
T62[D], T651	0.250–0.499	83.0	...	72.0	...	8	14
	0.500–1.000	84.0[G]	...	73.0[G]	...	6	...
	1.001–1.500	84.0[G]	...	73.0[G]	...	4	...
	1.501–2.000	80.0[G]	...	70.0[G]	...	3	...
T76	0.045–0.062	73.0	...	62.0	...	8	8
	0.063–0.091	73.0	...	62.0	...	8	9
	0.092–0.125	73.0	...	62.0	...	8	10
	0.126–0.187	73.0	...	62.0	...	8	11
	0.188–0.249	74.0	...	63.0	...	8	11
T7651	0.250–0.499	73.0	...	61.0	...	8	...
	0.500–1.000	73.0[G]	...	62.0[G]	...	6	...
F	All	...	...	...	...	...	...

[A] To determine conformance to this specification, each value for tensile strength and for yield strength shall be rounded to the nearest 0.1 ksi and each value for elongation to the nearest 0.5 %, both in accordance with the rounding method of Practice E 29.

[B] The basis for establishment of mechanical property limits is shown in Annex A1.

[C] Coiled sheet.

[D] Material in the T42, T62, and T72 tempers is not available from the material producer.

[E] For stress-relieved tempers (T351, T451, T651, T7351, T7651, and T851), characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.

[F] Test for tensile properties in the F temper are not required.

[G] The tension test specimen from plate 0.500 in. and thicker is machined from the core and does not include the cladding.

[H] Applicable to flat sheet and plate only.

[I] The T72 temper is applicable only to Alloys 2024 and Alclad 2024 sheet solution heat treated and artificially overaged by the user to develop increased resistance to stress-corrosion cracking.

[J] Short transverse tensile property limits are not applicable to material less than 1.500 in. in thickness.

[K] Use of Alloys 2219 and Alclad 2219 in the T31, T351, and T37 tempers for finished products is not recommended.

[L] The properties for this thickness apply only to the T651 temper.

TABLE 4 Lot Acceptance Criteria for Resistance to Stress Corrosion and Exfoliation Corrosion

Alloy and Temper	Lot Acceptance Criteria		Lot Acceptance Status
	Electrical Conductivity,[A] %, IACS	Level of Mechanical Properties	
7075-T73 and T7351	40.0 or greater	per specified requirements	acceptable
	38.0 through 39.9	per specified requirements yield strength does not exceed minimum by more than 11.9 ksi	acceptable
	38.0 through 39.9	per specified requirements but yield strength exceeds minimum by 12.0 ksi or more	unacceptable[B]
	less than 38.0	any level	unacceptable[B]
7075–*T76 and T7651* *Alclad* 7075–*T76 and T7651* *and* 7008 *Alclad* 7075–*T76 and* –*T7651*	38.0 or greater	per specified requirements	acceptable
	36.0 through 37.9	per specified requirements	unacceptable[B]
	less than 36.0	any level	unacceptable[B]
7178–*T76 and T7651* *Alclad* 7178–*T76 and T7651*	38.0 or greater	per specified requirements	acceptable
	35.0 through 37.9	per specified requirements	unacceptable[B]
7011 Alclad 7178-T76 and T7651	less than 35.0	any level	unacceptable[B]

[A] The electrical conductivity shall be determined in accordance with Test Method E 1004 in the following locations:

Alloy-Temper	Thickness, in.	Location
7075-T73 and T7351	all	surface of tension-test sample
7075–*T76 and T7651* 7178–*T76 and T7651*	up through 0.100	surface of tension-test sample
	0.101 and over	sub-surface after removal of approximately 10 % of the thickness

For alcad products, the cladding must be removed and the electrical conductivity determined on the core alloy.

[B] When material is found to be unacceptable, it shall be reprocessed (additional precipitation heat treatment or re-solution heat treatment, stress relieving and precipitation heat treatment, when applicable)..

TABLE 5 Components of Clad Products

Alloy	Component Alloys[A]		Total Composite Thickness of Finished Sheet and Plate, in.	Sides Clad	Cladding Thickness per Side, percent of Composite Thickness			
	Core	Cladding			Nominal	Average[B]		
						min	max	
Alclad 2014	2014	6003	up through 0.024	both	10	8		
			0.025–0.039	both	7.5	6		
			0.040–0.099	both	5	4		
			0.100 and over	both	2.5	2		
Alclad 2024	2024	1230	up through 0.062	both	5	4		
			0.063 and over	both	2.5	2		
1½ % Alclad 2024	2024	1230	0.188 and over	both	1.5	1.2	3[C]	
Alclad one-side 2024	2024	1230	up through 0.062	one	5	4		
			0.063 and over	one	2.5	2		
1½ % Alclad one-side 2024	2024	1230	0.188 and over	one	1.5	1.2	3[C]	
Alclad 2219	2219	7072	up through 0.039	both	10	8		
			0.040–0.099	both	5	4		
			0.100 and over	both	2.5	2		
Alclad 3003	3003	7072	all	both	5	4	6[D]	
Alclad 3004	3004	7072	all	both	5	4	6[D]	
Alclad 6061	6061	7072	all	both	5	4	6[D]	
Alclad 7075 and	7075	7072	*up through* 0.062	both	4	3.2		
7008 Alclad 7075	7075	7008	0.063–0.187	both	2.5	2		
			0.188 *and over*	both	1.5	1.2	3[C]	
Alclad one-side 7075	7075	7072	up through 0.062	one	4	3.2		
			0.063–0.187	one	2.5	2		
			0.188 and over	one	1.5	1.2	3[C]	
Alclad 7178	7178	7072	*up through* 0.062	both	4	3.2		
7011 Alclad 7178	7178	7011	0.063–0.187	both	2.5	2		
			0.188 *and over*	both	1.5	1.2	3[C]	

[A] Cladding composition is applicable only to the aluminum alloy bonded to the alloy ingot or slab preparatory to rolling to the specified composite product. The composition of the cladding may be altered subsequently by diffusion between the core and cladding due to thermal treatment.

[B] Average thickness per side as determined by averaging cladding thickness measurements when determined in accordance with the procedure specified in 15.2.

[C] For thicknesses of 0.500 in. and over with 1.5 % of nominal cladding thickness, the average maximum thickness of cladding per side after rolling to the specified thickness of plate shall be 3 % of the thickness of the plate as determined by averaging cladding thickness measurements taken at a magnification of 100 diameters on the cross section of a transverse sample polished and etched for examination with a metallurgical microscope.

[D] Applicable for thicknesses of 0.500 in. and greater.

TABLE 6 Ultrasonic Discontinuity Limits for Plate[A]

Alloy	Thickness, in.	Maximum Weight Per Piece, lb[B]	Discontinuity Class[C]
2014[D]	0.500–1.499	2000	B
2024[D]			
2124	1.500–3.000	2000	A
2219[D]			
7075[D]	3.001–6.000	2000	B
7178[D]			

[A] Discontinuities in excess of those listed in this table shall be allowed if it is established that they will be removed by machining or that they are in noncritical areas.
[B] The maximum weight is either the ordered weight of a plate of rectangular shape or the planned weight of a rectangular plate prior to removing metal to produce a part or plate shape to a drawing.
[C] The discontinuity class limits are defined in Section 11 of Practice B 594.
[D] Also applies for alclad plate.

ANNEXES

(Mandatory Information)

A1. BASIS FOR INCLUSION OF PROPERTY LIMITS

A1.1 Limits are established at a level at which a statistical evaluation of the data indicates that 99 % of the population obtained from all standard material meets the limit with 95 % confidence. For the products described, mechanical property limits for the respective size ranges are based on the analyses of at least 100 data from standard production material with no more than ten data from a given lot. All tests are performed in accordance with the appropriate ASTM test methods. For informational purposes, refer to "Statistical Aspects of Mechanical Property Assurance" in the Related Material section of the *Annual Book of ASTM Standards*, Vol 02.02.

A2. ACCEPTANCE CRITERIA FOR INCLUSION OF NEW ALUMINUM AND ALUMINUM ALLOYS IN THIS SPECIFICATION

A2.1 Prior to acceptance for inclusion in this specification, the composition of wrought or cast aluminum or aluminum alloy shall be registered in accordance with ANSI H35.1. The Aluminum Association[15] holds the Secretariat of ANSI H35 Committee and administers the criteria and procedures for registration.

A2.2 If it is documented that the Aluminum Association could not or would not register a given composition, an alternative procedure and the criteria for acceptance shall be as follows:

A2.2.1 The designation submitted for inclusion does not utilize the same designation system as described in ANSI H35.1. A designation not in conflict with other designation systems or a trade name is acceptable.

A2.2.2 The aluminum or aluminum alloy has been offered for sale in commercial quantities within the prior twelve months to at least three identifiable users.

A2.2.3 The complete chemical composition limits are submitted.

A2.2.4 The composition is, in the judgment of the responsible subcommittee, significantly different from that of any other aluminum or aluminum alloy already in the specification.

A2.2.5 For codification purposes, an alloying element is any element intentionally added for any purpose other than grain refinement and for which minimum and maximum limits are specified. Unalloyed aluminum contains a minimum of 99.00 % aluminum.

A2.2.6 Standard limits for alloying elements and impurities are expressed to the following decimal places:

Less than 0.001 %	0.000X
0.001 to but less than 0.01 %	0.00X
0.01 to but less than 0.10 %	
Unalloyed aluminum made by a refining process	0.0XX
Alloys and unalloyed aluminum not made by a refining process	0.0X
0.10 through 0.55 %	0.XX
(It is customary to express limits of 0.30 through 0.55 % as 0.X0 or 0.X5.)	
Over 0.55 %	0.X, X.X, etc.
(except that combined Si + Fe limits for 99.00 % minimum aluminum must be expressed as 0.XX or 1.XX)	

A2.2.7 Standard limits for alloying elements and impurities are expressed in the following sequence: Silicon; Iron; Copper; Manganese; Magnesium; Chromium; Nickel; Zinc (Note A2.1); Titanium; Other Elements, Each; Other Elements, Total; Aluminum (Note A2.2).

NOTE A2.1—Additional specified elements having limits are inserted in alphabetical order of their chemical symbols between zinc and titanium, or are specified in footnotes.

NOTE A2.2—Aluminum is specified as *minimum* for unalloyed aluminum and as a *remainder* for aluminum alloys.

[15] The Aluminum Association, 900 19th Street, NW, Washington, DC 20006.

SUMMARY OF CHANGES

This section identifies the principal changes to this standard that have been incorporated since the last issue.

(1) Paragraphs 4.1.8, 9.1.1 and 16.3 have been added.

(2) Paragraph 11.2 has been revised to add alloy 6061.

(3) Paragraphs 13.1 and 13.3.1 have been revised to add 2219-T851 and -T87.

(4) Note 6 has been added under 14.1.

(5) Paragraph 20.2 has been revised to add T3, T4, and 6061-T6 and T651.

(6) Table 2, bend diameter factors have been added for several alloy-temper-thickness combinations.

(7) Table 3, bend diameter factors have been added for many heat-treatable alloys.

(8) Table 3, superscript "K" has been added to T361 and T861 tempers for 2024 and Alclad 2024.

(9) Table 3, minimum elongation for Alclad 2024-T4, 0.021–0.062 in. has been revised.

(10) Table 3, 2124-T851 thickness range has been extended downward to 1.000 in.

(11) Table 3, 7075-T7351 tensile property limits have been added for 3.001–4.000 in.

(12) Table 3, 7011 Alclad 7075 and 7011 Alclad 7178 have been added.

(13) Table 6, plate thickness for ultrasonic inspection has been extended to 6.000 in.

(14) The tensile property limits for 7075-T76 sheet 0.063-0.124 in., 7075-T7651 plate 1.001–2.000 in., and Alclad 7075-T76 sheet 0.040-0.124 in. have been added.

(15) The tensile property limits for Alclad One Side 7075-T6 and T62 have been revised.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B21: Standard Specification for Naval Brass Rod, Bar, and Shapes

CFR Section(s): 46 CFR 56.60-2

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 21 – 96

Standard Specification for Naval Brass Rod, Bar, and Shapes[1]

This standard is issued under the fixed designation B 21; 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 specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope*

1.1 This specification establishes the requirements for naval brass rod, bar, and shapes produced from Copper Alloys UNS No. C46200, C46400, C47940, C48200, or C48500.

1.1.1 For piston-finish rod or shafting refer to Section 9.

1.2 This specification is the companion to SI Specification B 21M; therefore no SI equivalents are shown.

1.3 **Warning**—Mercury is a definite health hazard in use and disposal (see 8.1).

NOTE 1—For hot forging material, refer to Specification B 124.

2. Referenced Documents

2.1 *ASTM Standards:*

B 124 Specification for Copper and Copper-Alloy Forging Rod, Bar, and Shapes[2]

B 154 Test Method for Mercurous Nitrate Test for Copper and Copper Alloys[2]

B 249 Specification for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, and Shapes[2]

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[2]

E 8 Test Methods for Tension Testing of Metallic Materials[3]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[3]

E 478 Test Methods for Chemical Analysis of Copper Alloys[4]

3. Ordering Information

3.1 Orders for product under this specification are to include the following information:

3.1.1 ASTM designation and year of issue,

3.1.2 Copper Alloy UNS No. designation (Section 1.1),

3.1.3 Temper (Section 6),

3.1.4 Form: cross-section such as round, hexagonal, square, etc.,

3.1.5 Diameter or distance between parallel surfaces (Section 11.2),

3.1.6 Length (Section 11.4),

3.1.7 Edge contours (Section 11.6),

3.1.8 Number of pieces or total weight, for each size and form, and

3.1.9 When product is specified for agencies of the U.S. Government (Section 10).

3.2 The following are options available under this specification and are to be specified in the contract or purchase order when required:

3.2.1 Mercurous Nitrate Test (Section 8),

3.2.2 Piston finish rod or shafting (Section 9),

3.2.3 Certification (Specification B 249), and

3.2.4 Mill test report (Specification B 249).

4. General Requirements

4.1 The following sections of Specification B 249 constitute a part of this specification:

4.1.1 Terminology,

4.1.2 Materials and Manufacture,

4.1.3 Workmanship, Finish, and Appearance,

4.1.4 Sampling,

4.1.5 Number of Tests and Retests,

4.1.6 Specimen Preparation,

4.1.7 Test Methods,

4.1.8 Significance of Numerical Limits,

4.1.9 Inspection,

4.1.10 Rejection and Rehearing,

4.1.11 Certification,

4.1.12 Mill Test Report,

4.1.13 Packaging and Product Marking, and

4.1.14 Supplementary Requirements.

4.2 In addition, when a section with a title identical to that referenced in 4.1, above, appears in this specification, it contains additional requirements which supplement those appearing in Specification B 249.

5. Chemical Composition

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

5.2 These composition limits do not preclude the presence of other elements. Limits may be established and analysis required for unnamed elements by agreement between the manufacturer or supplier, and purchaser.

5.3 For copper alloys in which zinc is specified as the

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.02 on Rod, Bar, Wire, Shapes and Forgings.

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

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

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

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

TABLE 1 Chemical Requirements

Element, %	Copper Alloy UNS No.				
	C46200	C46400	C47940	C48200	C48500
Copper	62.0–65.0	59.0–62.0	63.0–66.0	59.0–62.0	59.0–62.0
Tin	0.50–1.0	0.50–1.0	1.2–2.0	0.50–1.0	0.50–1.0
Lead	0.20 max	0.20 max	1.0–2.0	0.40–1.0	1.3–2.2
Zinc	remainder	remainder	remainder	remainder	remainder
Iron	0.10 max	0.10 max	0.10–1.0	0.10 max	0.10 max
Nickel	...	...	0.10–0.50	...	...

remainder, either copper or zinc is permitted to be taken as the difference between the sum of results determined for all elements analyzed and 100 %. When copper is so determined, that difference value shall conform to the requirements given in Table 1.

5.4 When all elements listed in Table 1 for the Copper Alloy UNS No. specified in the ordering information are analyzed, the sum of results shall be 99.6 % minimum.

6. Temper

6.1 Tempers, as defined in Practice B 601, available under this specification are shown in Table 2.

7. Mechanical Property Requirements

7.1 The product shall conform to the mechanical property requirements given in Tables 2 and 3 for the Copper Alloy UNS No. designation specified in the ordering information.

7.1.1 *Rockwell Hardness*—For the alloys and tempers listed, the product ½ in. and over in diameter or distance between parallel surfaces shall conform with the requirements given in Table 3, when tested in accordance with Test Methods E 18.

7.1.1.1 For the alloys and tempers listed in Table 3, Rockwell hardness shall be the basis of acceptance or rejection for mechanical properties except when the tensile test is specified in the contract or purchase order.

7.1.2 *Tensile Strength*—The product shall conform with the requirements of Table 2, when tested in accordance with Test Methods E 8.

8. Mercurous Nitrate Test

8.1 When specified in the contract or purchase order, the test specimens, cut at least 6 in. in length, shall be totally immersed for 30 min in the standard mercurous nitrate solution specified in Test Method B 154. There shall be no cracks in the specimen when examined immediately after it is removed from the solution, rinsed and wiped.

NOTE 2: **Caution**—Mercury is a definite health hazard, and therefore equipment for the detection and removal of mercury vapor produced in volatilization is recommended. The use of rubber gloves in testing is advisable.

NOTE 3—Bars that have been properly straightened or sprung will have internal stresses so broken up as not to be in danger of splitting or cracking. The mercurous nitrate test is designed to determine whether the internal stresses have been properly broken up and rendered safe.

9. Piston-Finish Rod and Shafting

9.1 When so specified in the contract or order, round rods over ½-in. diameter shall be furnished as piston-finish rods or shafting.

9.2 Piston-finish rods shall have a special surface produced by turning or grinding and shall comply with the special diameter tolerances specified in 11.2.3.

9.3 The straightness tolerances for piston-finish rod are subject to agreement between the manufacturer or supplier and the purchaser.

10. Purchases for U.S. Government

10.1 Product purchased for agencies of the U.S. Government shall conform to the additional requirements prescribed in the Supplemental Requirements section of Specification B 249.

11. Dimensions, Mass, and Permissible Variations

11.1 The dimensions and tolerances for material covered by this specification shall be as specified in the current edition of Specification B 249, with particular reference to Section 5 and the following tables of that specification:

11.2 *Diameter or Distance Between Parallel Surfaces:*

11.2.1 *Rod: Round, Hexagonal, Octagonal*—See 5.2, Table 1.

11.2.2 *Rod, M30 (As-Hot Extruded)*—See 5.2, Table 4.

11.2.3 *Piston-Finish Rod*—See 5.2, Table 3.

11.2.4 *Bar: Rectangular and Square*—See 5.2, Tables 8 and 10.

11.2.5 *Bar, M30 (As-Hot Extruded)*—See 5.2, Table 4.

11.3 *Shapes*—The dimensional tolerances for shapes shall be as agreed upon by the manufacturer or supplier and the purchaser, and shall be specified in the order.

11.4 *Length of Rod, Bar, and Shapes*—See 5.3, Tables 13 and 14.

11.5 *Straightness:*

11.5.1 *Rod and Bar*—See 5.4.1, Table 16.

11.5.2 *Shafting Rod*—See 5.4.2, Table 17.

11.5.3 M30 (as-hot extruded) rod, bar, and shapes shall be commercially straight.

11.6 *Edge Contours*—See 5.5.

12. Specimen Preparation

12.1 In the tension test all material shall be pulled in full size when practicable. Full-size or machined test specimens shall be as specified in Test Methods E 8. Whenever tension test results are obtained from both full-size and from machined test specimens and they differ, the results obtained from full-size test specimens shall be used to determine conformance to the requirements of this specification.

NOTE 4—The tension test specimens shall conform to the dimensions specified in Section 6 of Test Methods E 8.

12.2 Mercurous nitrate test specimens shall be of the full size of the material, and without bending, springing, polishing, or any other preparation.

13. Test Methods

13.1 *Chemical Analysis:*

13.1.1 Chemical composition shall be determined, in case of disagreement, as follows:

Element	ASTM Test Method
Copper	E 478
Iron	E 478
Lead	E 478 (AA)
Nickel	E 478
Tin	E 478 (Titrimetric)
Zinc	E 478 (Titrimetric)

TABLE 2 Tensile Requirements

Temper Designation		Diameter or Distance Between Parallel Surfaces, in.	Tensile Strength, min, ksi	Yield Strength at 0.5 % Extension Under Load, min, ksi	Elongation in 4 × Diameter of Thickness of Specimen, min, %[A]
Standard	Former				
		Copper Alloy UNS No. C46200			
M30	as-hot extruded	all forms, all sizes	50	20	30
O60	soft anneal	rods and bars, all sizes	48	16	30
O50	light anneal	rods and bars:			
		0.500 and under	58	27	22
		over 0.500 to 1.000, incl	56	27	25
		over 1.000 to 2.000, incl	54	26	25
		over 2.000 to 3.000, incl	52	25	27
		over 3.000 to 4.000, incl	50	22	30
		over 4.000	50	20	30
H60	cold heading, forming	rods, all sizes	48	18	22
H02	half-hard	rods and bars:			
		0.500 and under	58	27	22
		over 0.500 to 1.000, incl	56	27	25
		over 1.000 to 2.000, incl	54	26	25
		over 2.000 to 3.000, incl	52	25	27
		over 3.000 to 4.000, incl	50	22	30
		over 4.000	50	20	30
H04	hard	rods and bars:			
		0.500 and under	64	40	13
		over 0.500 to 1.000, incl	62	38	13
		over 1.000 to 2.000, incl	58	34	18
		Copper Alloy UNS No. C46400			
M30	as-hot extruded	all forms, all sizes	52	20	30
O60	soft anneal	rods and bars:			
		1.000 and under	54	20	30
		over 1.000 to 2.000, incl	52	20	30
		over 2.000	50	20	30
		shapes, all sizes	52	20	30
O50	light anneal	rods and bars:			
		0.500 and under	60	27	22
		over 0.500 to 1.000, incl	60	27	25
		over 1.000 to 2.000, incl	58	26	25
		over 2.000 to 3.000, incl	54	25	25
		over 3.000 to 4.000, incl	54	22	27
		over 4.000	54	22	30
H50[B]	extruded and drawn[B]	shapes, all sizes	58	25	20
H02	half-hard	rods and bars:			
		0.500 and under	60	27	22
		over 0.500 to 1.000, incl	60	27	25
		over 1.000 to 2.000, incl	58	26	25
		over 2.000 to 3.000, incl	54	25	25
		over 3.000 to 4.000, incl	54	22	27
		over 4.000	54	22	30
H04	hard	rods and bars:			
		1.000 and under	67	45	13
		over 1.000 to 2.000, incl	62	37	18
		Copper Alloy UNS No. C47940			
M30	as-hot extruded	all forms, all sizes	50	20	30
O60	soft anneal	rods and bars, all sizes	48	20	30
O50	light anneal	rods and bars:			
		0.500 and under	58	30	18
		over 0.500 to 1.000, incl	56	30	20
		over 1.000 to 2.000, incl	54	25	22
		over 2.000	50	25	25
H50[B]	extruded and drawn[B]	shapes, all sizes	56	25	20
H02	half-hard	rods and bars:			
		0.500 and under	58	30	18
		over 0.500 to 1.000, incl	56	30	20
		over 1.000 to 2.000, incl	54	25	22
		over 2.000	50	25	25
H04	hard	rods and bars:			
		0.500 and under	70	55	10
		over 0.500 to 1.000, incl	65	52	13
		over 1.000 to 2.000, incl	62	45	15

TABLE 2 *Continued*

Temper Designation		Diameter or Distance Between Parallel Surfaces, in.	Tensile Strength, min, ksi	Yield Strength at 0.5 % Extension Under Load, min, ksi	Elongation in 4 × Diameter of Thickness of Specimen, min, %[A]
Standard	Former				
		Copper Alloy UNS No. C48200			
M30	as-hot extruded	all forms, all sizes	52	20	25
O60	soft anneal	rods and bars:			
		1.000 and under	54	20	25
		over 1.000 to 2.000, incl	52	20	25
		over 2.000	50	20	25
		shapes, all sizes	52	20	25
O50	light anneal	rods and bars:			
		1.000 and under	60	27	18
		over 1.000 to 2.000, incl	58	26	20
		over 2.000 to 3.000, incl	54	25	20
		over 3.000 to 4.000, incl	54	22	20
		over 4.000	54	22	25
H50[B]	extruded and drawn[B]	shapes, all sizes	58	25	15
H02	half-hard	rods and bars:			
		1.000 and under	60	27	18
		over 1.000 to 2.000, incl	58	26	20
		over 2.000 to 3.000, incl	54	25	20
		over 3.000 to 4.000, incl	54	22	20
		over 4.000	54	22	25
H04	hard	rods and bars:			
		1.000 and under	67	45	11
		over 1.000 to 2.000, incl	62	37	15
		Copper Alloy UNS No. C48500			
M30	as-hot extruded	all forms, all sizes	52	20	20
O60	soft anneal	rods and bars:			
		1.000 and under	54	20	20
		over 1.000 to 2.000, incl	52	20	20
		over 2.000	50	20	20
		shapes, all sizes	52	20	20
O50	light anneal	rods and bars:			
		1.000 and under	60	27	12
		over 1.000 to 2.000, incl	58	26	20
		over 2.000 to 3.000, incl	54	25	20
		over 3.000 to 4.000, incl	54	22	20
		over 4.000	54	22	20
H50[B]	extruded and drawn[B]	shapes, all sizes	58	25	15
H02	half-hard	rods and bars:			
		1.000 and under	60	27	12
		over 1.000 to 2.000, incl	58	26	20
		over 2.000 to 3.000, incl	54	25	20
		over 3.000 to 4.000, incl	54	22	20
		over 4.000	54	22	20
H04	hard	rods and bars:			
		1.000 and under	67	45	10
		over 1.000 to 2.000, incl	62	37	13

[A] In any case, a minimum gage length of 1 in. shall be used.
[B] This temper does not apply to hollow shapes.

TABLE 3 Rockwell Hardness Requirements

NOTE—Rockwell Hardnesses are not established for diameters less than ½ in.

Copper Alloy UNS No.	Temper Designation		Diameter or Distance Between Parallel Surfaces, in.	Rockwell B Hardness Determined on the Cross-Section Midway Between Surface and Center
	Standard	Former		
C46400	H02	half-hard	over 0.500 to 1.000, incl	60–80
			over 1.000	55–80
	H04	hard	over 0.500 to 1.000, incl	70–90
			over 1.000	65–90
C48200	H02	half-hard	over 0.500 to 1.000, incl	65–85
			over 1.000	60–85
	H04	hard	over 0.500 to 1.000, incl	70–90
			over 1.000	65–90
C48500	H02	half-hard	over 0.500 to 1.000, incl	65–85
			over 1.000	60–85
	H04	hard	over 0.500 to 1.000, incl	70–90
			over 1.000	65–90

13.1.2 Test method(s) to be followed for the determination of element(s) resulting from contractural or purchase order agreement shall be agreed upon between the supplier and purchaser.

14. Keywords

14.1 naval brass; naval brass bar; naval brass rod; piston-finish rod; piston-finish shafting

SUMMARY OF CHANGES

The following is a summary of the changes that have been incorporated since the printing of B 21 – 90:

1. The Scope section was revised, and the previously used alloy designation deleted.
2. The Ordering information section revised to more clearly delineate purchasing options.
3. The General Requirements section revised to identify the specific sections in Specification B 249 which constitute a part of this specification.
4. Table 2 was revised to more clearly state the mechanical property requirements.
5. A Test Methods section was added to identify individual test methods for the determination of chemical composition.
6. Table 3 was added to show the Rockwell hardness requirements for the alloys and tempers listed.

Designation: B 21M – 96
METRIC

Standard Specification for Naval Brass Rod, Bar, and Shapes [Metric][1]

This standard is issued under the fixed designation B 21M; 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 specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope*

1.1 This specification establishes the requirements for naval brass rod, bar, and shapes produced from Copper Alloys UNS Nos. C46200, C46400, C47940, C48200, or C48500.

1.1.1 For piston-finish rod or shafting, refer to Section 9.

1.2 This specification is the companion to inch-pound Specification B 21.

1.3 **Warning**—Mercury is a definite health hazard in use and disposal (see 8.1).

NOTE 1—For hot forging material, refer to Specification B 124.

2. Referenced Documents

2.1 *ASTM Standards:*

B 124M Specification for Copper and Copper-Alloy Forging Rod, Bar, and Shapes [Metric][2]

B 154 Test Method for Mercurous Nitrate Test for Copper and Copper Alloys[2]

B 249M Specification for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, and Shapes [Metric][2]

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[2]

E 8M Test Methods for Tension Testing of Metallic Materials [Metric][3]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness[3]

E 478 Test Methods for Chemical Analysis of Copper Alloys[4]

3. Ordering Information

3.1 Orders for product under this specification are to include the following information:

3.1.1 ASTM designation and year of issue,

3.1.2 Copper Alloy UNS No. designation (Section 1.1),

3.1.3 Temper (Section 6),

3.1.4 Form: cross-section such as round, hexagonal, square, etc.,

3.1.5 Diameter or distance between parallel surfaces (Section 11.2),

3.1.6 Length (Section 11.4),

3.1.7 Edge contours (Section 11.6),

3.1.8 Number of pieces or total weight, for each size and form, and

3.1.9 When product is specified for agencies of the U.S. Government (Section 10).

3.2 The following are options available under this specification and are to be specified in the contract or purchase order when required:

3.2.1 Mercurous Nitrate Test (Section 8),

3.2.2 Piston finish rod or shafting (Section 9),

3.2.3 Certification (Specification B 249M), and

3.2.4 Mill test report (Specification B 249M).

4. General Requirements

4.1 The following sections of Specification B 249M constitute a part of this specification:

4.1.1 Terminology,

4.1.2 Materials and Manufacture,

4.1.3 Workmanship, Finish, and Appearance,

4.1.4 Sampling,

4.1.5 Number of Tests and Retests,

4.1.6 Specimen Preparation,

4.1.7 Test Methods,

4.1.8 Significance of Numerical Limits,

4.1.9 Inspection,

4.1.10 Rejection and Rehearing,

4.1.11 Certification,

4.1.12 Mill Test Report,

4.1.13 Packaging and Product Marking, and

4.1.14 Supplementary Requirements.

4.2 In addition, when a section with a title identical to that referenced in 4.1, above, appears in this specification, it contains additional requirements which supplement those appearing in Specification B 249M.

5. Chemical Composition

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

5.2 These composition limits do not preclude the presence of other elements. Limits may be established and analysis required for unnamed elements by agreement between the manufacturer or supplier, and purchaser.

5.3 For copper alloys in which zinc is specified as the

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.02 on Rod, Bar, Wire, Shapes and Forgings.

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

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

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

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

TABLE 1 Chemical Requirements

Element, %	Copper Alloy UNS No.				
	C46200	C46400	C47940	C48200	C48500
Copper	62.0–65.0	59.0–62.0	63.0–66.0	59.0–62.0	59.0–62.0
Tin	0.50–1.0	0.50–1.0	1.2–2.0	0.50–1.0	0.50–1.0
Lead	0.20 max	0.20 max	1.0–2.0	0.40–1.0	1.3–2.2
Zinc	remainder	remainder	remainder	remainder	remainder
Iron	0.10 max	0.10 max	0.10–1.0	0.10 max	0.10 max
Nickel	...	...	0.10–0.50	...	...

remainder, either copper or zinc is permitted to be taken as the difference between the sum of results determined for all elements analyzed and 100 %. When copper is so determined, that difference value shall conform to the requirements given in Table 1.

5.4 When all elements listed in Table 1 for the Copper Alloy UNS No. specified in the ordering information are analyzed, the sum of results shall be 99.6 % minimum.

6. Temper

6.1 Tempers, as defined in Practice B 601, available under this specification are shown in Table 2.

7. Mechanical Property Requirements

7.1 The product shall conform to the mechanical property requirements given in Tables 2 and 3 for the Copper Alloy UNS No. designation specified in the ordering information.

7.1.1 *Rockwell Hardness*—For the alloys and tempers listed, the product 12 mm and over in diameter or distance between parallel surfaces shall conform with the requirements given in Table 3, when tested in accordance with Test Methods E 18.

7.1.1.1 For the alloys and tempers listed in Table 3, Rockwell hardness shall be the basis of acceptance or rejection for mechanical properties except when the tensile test is specified in the contract or purchase order.

7.1.2 *Tensile Strength*—The product shall conform with the requirements of Table 2, when tested in accordance with Test Methods E 8M.

8. Mercurous Nitrate Test

8.1 When specified in the contract or purchase order, the test specimens, cut at least 150 mm in length, shall be totally immersed for 30 min in the standard mercurous nitrate solution specified in Method B 154. There shall be no cracks in the specimen when examined immediately after it is removed from the solution, rinsed, and wiped.

NOTE 2: **Precaution**—Mercury is a definite health hazard, and therefore equipment for the detection and removal of mercury vapor produced in volatilization is recommended. The use of rubber gloves in testing is advisable.

NOTE 3—Bars that have been properly straightened or sprung will have internal stresses so broken up as not to be in danger of splitting or cracking. The mercurous nitrate test is designed to determine whether the internal stresses have been properly broken up and rendered safe.

9. Piston-Finish Rod and Shafting

9.1 When so specified in the contract or order, round rods over 12 mm in diameter shall be furnished as piston-finish rods or shafting.

9.2 Piston-finish rods shall have a special surface produced by turning or grinding and shall comply with the special diameter tolerances specified in 11.2.3.

9.3 The straightness tolerances for piston-finish rod are subject to agreement between the manufacturer or supplier and the purchaser.

10. Purchases for U.S. Government

10.1 Product purchased for agencies of the U.S. Government shall conform to the additional requirements prescribed in the Supplemental Requirements section of Specification B 249M.

11. Dimensions, Mass, and Permissible Variations

11.1 The dimensions and tolerances for material covered by this specification shall be as specified in the current edition of Specification B 249M, with particular reference to Section 5 and the following tables of that specification.

11.2 *Diameter or Distance Between Parallel Surfaces:*

11.2.1 *Rod: Round, Hexagonal, Octagonal*—See 5.2, Table 1.

11.2.2 *Rod, M30, (As-Hot Extruded)*—See 5.2, Table 4.

11.2.3 *Piston-Finish Rod*—See 5.2, Table 3.

11.2.4 *Bar: Rectangular and Square*—See 5.2, Tables 8 and 10.

11.2.5 *Bar, M30, (As-Hot Extruded)*—See 5.2, Table 4.

11.3 *Shapes*—The dimensional tolerances for shapes shall be as agreed upon by the manufacturer or supplier and the purchaser, and shall be specified in the order.

11.4 *Length of Rod, Bar, and Shapes*—See 5.3, Tables 13 and 14.

11.5 *Straightness:*

11.5.1 *Rod and Bar*—See 5.4.1, Table 16.

11.5.2 *Shafting Rod*—See 5.4.2, Table 17.

11.5.3 *M30 (As-Hot Extruded)* rod, bar, and shapes shall be commercially straight.

11.6 *Edge Contours*—See 5.5.

12. Test Specimens

12.1 In the tension test all material shall be pulled in full size when practicable. Full-size or machined test specimens shall be as specified in Test Methods E 8. Whenever tension test results are obtained from both full-size and from machined test specimens and they differ, the results obtained from full-size test specimens shall be used to determine conformance to the requirements of this specification.

NOTE 4—The tension test specimens shall conform to the dimensions specified in Section 6 of Test Methods E 8M.

12.2 Mercurous nitrate test specimens shall be of the full size of the material, and without bending, springing, polishing, or any other preparation.

13. Test Methods

13.1 *Chemical Analysis:*

13.1.1 Chemical composition shall be determined, in case of disagreement, as follows:

Element	ASTM Test Method
Copper	E 478
Iron	E 478
Lead	E 478 (AA)
Nickel	E 478
Tin	E 478 (Titrimetric)
Zinc	E 478 (Titrimetric)

TABLE 2 Tensile Requirements

Temper Designation		Diameter or Distance Between Parallel Surfaces, mm	Tensile Strength, min, MPa	Yield Strength at 0.5 % Extension Under Load, min, MPa	Elongation,[A] min, %
Standard	Former				
		Copper Alloy UNS Nos. C46200			
M30	as-hot extruded	all forms, all sizes	345	140	30
O60	soft anneal	rods and bars, all sizes	330	110	30
O50	light anneal	rods and bars:			
		12 and under	400	185	22
		over 12 to 25, incl	385	185	25
		over 25 to 50, incl	370	180	25
		over 50 to 75, incl	360	170	27
		over 75 to 100, incl	345	150	30
		over 100	345	140	30
H60	cold heading, forming	rods, all sizes	330	125	22
H02	half-hard	rods and bars:			
		12 and under	400	185	22
		over 12 to 25, incl	385	185	25
		over 25 to 50, incl	370	180	25
		over 50 to 75, incl	360	170	27
		over 75 to 100, incl	345	150	30
		over 100	345	140	30
H04	hard	rods and bars:			
		12 and under	440	275	13
		over 12 to 25, incl	425	260	13
		over 25 to 50, incl	400	235	18
		Copper Alloy UNS No. C46400			
M30	as-hot extruded	all forms, all sizes	360	140	30
O60	soft anneal	rods and bars:			
		25 and under	370	140	30
		over 25 to 50, incl	360	140	30
		over 50	345	140	30
		shapes, all sizes	360	140	30
O50	light anneal	rods and bars:			
		12 and under	415	185	22
		over 12 to 25, incl	415	185	25
		over 25 to 50, incl	400	180	25
		over 50 to 75, incl	370	170	25
		over 75 to 100, incl	370	150	27
		over 100	370	150	30
H50[B]	extruded and drawn[B]	shapes, all sizes	400	170	20
H02	half-hard	rods and bars:			
		12 and under	415	185	22
		over 12 to 25, incl	415	185	25
		over 25 to 50, incl	400	180	25
		over 50 to 75, incl	370	170	25
		over 75 to 100, incl	370	150	27
		over 100	370	150	30
H04	hard	rods and bars:			
		25 and under	460	310	13
		over 25 to 50, incl	425	255	18
		Copper Alloy UNS No. C47940			
M30	as extruded	all forms, all sizes	345	140	30
O60	soft anneal	rods and bars, all sizes	330	140	30
O50	light anneal	rods and bars:			
		12 and under	400	210	18
		over 12 to 25, incl	390	210	20
		over 25 to 50, incl	375	175	22
		over 50	345	175	25
H50[B]	extruded and drawn[B]	shapes, all sizes	390	175	20
H02	half-hard	rods and bars:			
		12 and under	400	210	18
		over 12 to 25, incl	390	210	20
		over 25 to 50, incl	375	175	22
		over 50	345	175	25
H04	hard	rods and bars:			
		12 and under	485	380	10
		over 12 to 25, incl	450	360	13
		over 25 to 50, incl	430	310	15

TABLE 2 *Continued*

Temper Designation		Diameter or Distance Between Parallel Surfaces, mm	Tensile Strength, min, MPa	Yield Strength at 0.5 % Extension Under Load, min, MPa	Elongation,[A] min, %
Standard	Former				
		Copper Alloy UNS No. C48200			
M30	as-hot extruded	all forms, all sizes	360	140	25
O60	soft anneal	rods and bars:			
		25 and under	370	140	25
		over 25 to 50, incl	360	140	25
		over 50	345	140	25
		shapes, all sizes	360	140	25
O50	light anneal	rods and bars:			
		25 and under	415	185	18
		over 25 to 50, incl	400	180	20
		over 50 to 75, incl	370	170	20[A]
		over 75 to 100, incl	370	150	20
		over 100	370	150	25
H50[B]	extruded and drawn[B]	shapes, all sizes	400	170	15
H02	half-hard	rods and bars:			
		25 and under	415	185	18
		over 25 to 50, incl	400	180	20
		over 50 to 75, incl	370	170	20[A]
		over 75 to 100, incl	370	150	20
		over 100	370	150	25
H04	hard	rods and bars:			
		25 and under	460	310	11
		over 25 to 50, incl	425	255	15
		Copper Alloy UNS No. C48500			
M30	as-hot extruded	all forms, all sizes	360	140	20
O60	soft anneal	rods and bars:			
		25 and under	370	140	20
		over 25 to 50, incl	360	140	20
		over 50	345	140	20
		shapes, all sizes	360	140	20
O50	light anneal	rods and bars:			
		25 and under	415	185	12
		over 25 to 50, incl	400	180	20
		over 50 to 75, incl	370	170	20
		over 75 to 100, incl	370	150	20
		over 100	370	150	20
H50[B]	extruded and drawn[B]	shapes, all sizes	400	170	15
H02	half-hard	rods and bars:			
		25 and under	415	185	12
		over 25 to 50, incl	400	180	20
		over 50 to 75, incl	370	170	20
		over 75 to 100, incl	370	150	20
		over 100	370	150	20
H04	hard	rods and bars:			
		25 and under	460	310	10
		over 25 to 50, incl	425	255	13

[A] Elongation values are based on a gage length of 5.65 times the square root of the area for dimensions greater than 2.5 mm.
[B] This temper does not apply to hollow shapes.

TABLE 3 Rockwell Hardness Requirements

NOTE—Rockwell hardnesses are not established for diameters below 12 mm.

Copper Alloy UNS No.	Temper Designation		Diameter or Distance Between Parallel Surfaces, mm	Rockwell B Hardness Determined on the Cross-Section Midway Between Surface and Center
	Standard	Former		
C46400	H02	half-hard	over 12 to 25, incl	60–80
			over 25	55–80
	H04	hard	over 12 to 25, incl	70–90
			over 25	65–90
C48200	H02	half-hard	over 12 to 25, incl	65–85
			over 25	60–85
	H04	hard	over 12 to 25, incl	70–90
			over 25	65–90
C48500	H02	half-hard	over 12 to 25, incl	65–85
			over 25	60–85
	H04	hard	over 12 to 25, incl	70–90
			over 25	65–90

13.1.2 Test method(s) to be followed for the determination of element(s) resulting from contractural or purchase order agreement shall be agreed upon between the supplier and purchaser.

14. Keywords

14.1 naval brass; naval brass bar; naval brass rod; piston-finish rod; piston-finish shafting

SUMMARY OF CHANGES

The following is a summary of the changes that have been incorporated since the printing of B 21M – 90:

1. The Scope section was revised, and the previously used alloy designation deleted.
2. The Ordering information section revised to more clearly delineate purchasing options.
3. The General Requirements section revised to identify the specific sections in Specification B 249M which constitute a part of this specification.
4. Table 2 was revised to more clearly state the mechanical property requirements.
5. A Test Methods section was added to identify individual test methods for the determination of chemical composition.
6. Table 3 was added to show the Rockwell hardness requirements for the alloys and tempers listed.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B224: Standard Classification of Coppers

CFR Section(s): 7 CFR 1755.890(i)(5)(vi)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 224 – 80[ε1]

Standard Classification of COPPERS[1]

This standard is issued under the fixed designation B 224; 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 classification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

[ε1] NOTE—Reference to "lake copper" has been deleted from Table A1 in October 1982 because such terminology is no longer used.

1. Scope

1.1 This is a classification of the various types of copper currently available in refinery shapes and wrought products in commercial quantities. It is not a specification for the various types of copper.

1.2 In this classification, use is made of the standard copper designations in use by the copper industry.

1.3 Although this classification includes certain UNS designations as described in Practice E 527, these designations are for cross-reference only and are not requirements. Therefore, in case of conflict, this ASTM classification shall govern.

1.4 This classification does not attempt to differentiate between all compositions that could be termed either coppers or copper-base alloys, but in conformance with general usage in the trade, includes those coppers in which the copper is specified as 99.85 % or more, silver being counted as copper.

NOTE 1—Coppers may contain small amounts of certain elements intentionally permitted to impart specific properties, without excessively lowering electrical conductivity. The total copper plus specific permitted elements is usually specified as 99.85 % or more. These intentionally permitted elements normally include, but are not limited to, arsenic, cadmium, chromium, lead, magnesium, silver, sulfur, tellurium, tin, zinc, and zirconium, plus deoxidizers, up to specific levels adopted by the International Standards Organization.

2. Applicable Documents

2.1 *ASTM Standards:*

B 30 Specification for Copper-Base Alloys in Ingot Form[2]

B 170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes[3]

B 379 Specification for Phosphorized Coppers—Refinery Shapes[3]

B 584 Specification for Copper Alloy Sand Castings for General Applications[2]

E 527 Practice for Numbering Metals and Alloys (UNS)[4]

3. Basis of Classification

3.1 Table A1 lists the standard designations, and the refinery shapes and fabricators' products currently produced. The listed coppers are not necessarily available in the complete range of sizes in the form shown, nor from any one supplier in all forms.

3.2 Existing ASTM specifications for refinery copper and for wrought copper products may cover more than one of the coppers listed in Table A1 or may include only part of the range covered by any one of the coppers shown in this classification.

4. Description of Terms

4.1 Appendix A2 describes the terms used in designating the various coppers listed.

4.2 Appendix A3 describes the refinery shapes.

4.3 Appendix A4 describes the fabricators' forms.

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[1] This classification is under the jurisdiction of ASTM Committee B-2 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.01 on Refined Copper.

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

[3] *Annual Book of ASTM Standards*, Vol 02.04.

[4] *Annual Book of ASTM Standards*, Vols 02.01, 02.02, 02.03, 02.04, 02.05, and 03.01.

NOTE 2—Copper, as applied to castings other than refinery cast shapes, cakes, billets, wire bars, ingots, and ingot bars, is described in Specifications B 30 and B 584.

APPENDIXES

A1. CLASSIFICATION OF COPPERS

A1.1 Table A1 lists the standard designations, refinery shapes, and fabricator's products.

A2. TERMS USED TO DESIGNATE THE COPPERS

(Alphabetical listing of these terms does not necessarily indicate relative order of commercial importance.)

A2.1 Terms Relating to Method of Refining

A2.1.1 *chemically refined copper*—copper recovered from an aqueous solution by other than electrolytic means. Usually when this term is used alone it refers to chemically refined tough pitch copper. This designation applies to the following:

A2.1.1.1 Copper cast in refinery shapes suitable for hot or cold working or both, and by extension, to fabricators products made therefrom.

A2.1.1.2 Ingots or ingot bars suitable for remelting.

A2.1.2 *electrolytic copper*—copper of any origin, refined by electrolytic deposition including electrowinning. Usually when this term is used alone it refers to electrolytic tough pitch copper. This designation applies to the following:

A2.1.2.1 Cathodes that are the direct product of the refining operation.

A2.1.2.2 Electrodeposited copper cast in refinery shapes suitable for hot or cold working or both, and by extension, to fabricators' products made therefrom.

A2.1.2.3 Electrodeposited copper cast into ingots or ingot bars suitable for remelting.

A2.1.3 *fire-refined copper*—copper of any origin or type finished by furnace refining without having been processed at any stage by electrolytic or chemical refining. Usually when the term fire-refined copper is used alone it refers to fire-refined tough pitch copper. This designation applies to the following:

A2.1.3.1 Copper cast in refinery shapes suitable for hot or cold working or both, and by extension, to fabricators' products made therefrom.

A2.1.3.2 Ingots or ingot bars suitable for remelting.

A2.2 Terms Relating to Characteristics Determined by Method of Casting or Processing

A2.2.1 *deoxidized copper*—copper cast in the form of refinery shapes, produced free of cuprous oxide, as determined by metallographic examination at 75× under polarized light, by the use of metallic or metalloidal deoxidizers. Oxygen may be present as residual deoxidation products. By extension, the term applies to fabricators' products made therefrom.

A2.2.2 *oxygen-free copper*—electrolytic copper produced free of cuprous oxide, as determined by metallographic examination at 75× under polarized light, without the use of metallic or metalloidal deoxidizers. By extension, the term applies to fabricators' products made therefrom.

A2.2.3 *tough pitch copper*—copper of any origin cast in the form of refinery shapes, containing a controlled amount of oxygen in the form of cuprous oxide. By extension the term is also applicable to fabricators' products made therefrom.

A2.3 Terms Relating to Specific Kinds of Copper and to Products Made Therefrom

A2.3.1 *deoxidized copper, high-residual phosphorus*—copper deoxidized with phosphorus residual in amounts 0.015 to 0.04 %. The copper is not susceptible to hydrogen embrittlement, as determined in Specification B 379. The copper is of relatively low-electrical conductivity due to the amount of phosphorus present.

NOTE—International Standards Organization specifications permit up to 0.050 % phosphorus.

A2.3.2 *deoxidized copper, low-residual phosphorus*—copper deoxidized with phosphorous residual in amounts 0.004 to 0.012 %. The copper is not readily susceptible to hydrogen embrittlement, as determined in Specification B 379. The copper in the annealed condition has a minimum conductivity of 98.16 % IACS.

A2.3.3 *high-conductivity copper*—copper that in the annealed condition has a minimum electrical conductivity of 100 % IACS.

A2.3.4 *oxygen-free electronic copper*—high-purity, high-conductivity oxygen-free copper normally intended for electronic applications. The copper has high resistance to hydrogen embrittlement, as determined in Specification B 170. The copper in the annealed condition has a minimum electrical conductivity of 101 % IACS.

A2.3.5 *oxygen-free copper, extra low phosphorus*—oxygen-free copper containing 0.001 to 0.005 % phosphorus. The copper is not readily susceptible to hydrogen embrittlement, as determined in Specification

B 379. The copper in the annealed condition has a minimum conductivity of 98.16 % IACS.

A2.3.6 *oxygen-free copper, low phosphorus*—oxygen-free copper containing 0.005 to 0.012 % phosphorus. The copper is not susceptible to hydrogen embrittlement, as determined in Specification B 379. The copper in the annealed condition has a minimum conductivity of 90 % IACS.

A2.3.7 *deoxidized, phosphorus-arsenical copper.*

A2.3.8 *arsenical, tough-pitch copper.*

A2.3.9 *silver-bearing copper.*

A2.3.10 *sulfur-bearing copper.*

A2.3.11 *deoxidized, phosphorus-tellurium copper.*

A2.3.12 *zirconium-bearing copper.*

NOTE—Coppers listed in A2.3.7 through A2.3.12 contain the designated element or elements in amounts as agreed upon between the manufacturer or supplier and the purchaser.

A3. DEFINITIONS OF REFINERY SHAPES

A3.1 *billet*—refinery shape used for piercing or extrusion into tubular products or for extrusion into rods, bars, and shapes. Circular in cross section, usually 3 to 16 in. (76 to 406 mm) in diameter, normally ranging in weight from 100 to 4200 lb (45 to 1905 kg).

A3.2 *cake*—refinery shape used for rolling into plate, sheet, strip, or shape. Rectangular in cross section and of various sizes, normally ranging in weight from 140 to 62 000 lb (63 to 28 200 kg).

A3.3. *cathode*—unmelted, electrodeposited, and somewhat rough flat plate normally used for melting. The customary size is about 3 ft (0.914 m) square, about ½ to ⅞ in. (12.7 to 22.2 mm) thick, weighing up to about 300 lb (136 kg), and may have hanging loops attached. Cathodes may also be cut to smaller dimensions.

A3.4 *ingot and ingot bar*—refinery shapes used for remelting (not fabrication). Ingots normally range in weight from 20 to 35 lb (9 to 16 kg) and ingot bars from 50 to 70 lb (23 to 32 kg). Both are usually notched to facilitate breaking into smaller pieces.

A3.5 *wire bar*—refinery shape used for rolling into rod or flat product for subsequent processing into wire, strip, or shape. Approximately 3½ to 5 in. (89 to 127 mm) square in cross section, usually 54 in. (1.56 m) in length and ranging in weight from 200 to 420 lb (91 to 191 kg). Usually tapered at both ends.

A4. DEFINITIONS OF FABRICATORS' COPPER PRODUCTS

A4.1 *flat product*—a rectangular or square solid section of relatively great length in proportion to thickness. Included in the designation "flat product" depending on the width and thickness, are plate, sheet, strip, and bar. Also included is the product known as "flat wire."

A4.2 *pipe*—tube conforming to the particular dimensions commerically known as "Standard Pipe Sizes."

A4.3 *rod*—a solid section, round, hexagonal, or octagonal in straight lengths. Round rod for further processing into wire (known as "hot-rolled rod," "wire-rod," "redraw wire," or "drawing stock") is furnished coiled.

A4.4 *shape*—a solid section, other than flat product, rod or wire, furnished in straight lengths. Shapes are usually made by extrusion but may also be fabricated by drawing.

A4.5 *tube*—a unidirectionally elongated hollow product of uniform round or other cross section having a continuous periphery.

A4.6 *wire*—a solid section, including rectangular flat wire but excluding other flat products, furnished in coils or on spools, reels, or bucks.

TABLE A1 Classification of Coppers

Designations	Type of Cooper[A]	UNS Nos.[B]	Form in which Copper is Available[C]							
			From Refiners[D]				From Fabricators[E]			
			Wire Bars	Billets	Cakes	Ingots and Ingot Bars	Flat Products	Pipe and Tube	Rod and Wire	Shapes
CATH	Electrolytic cathode		Cathodes only							
		Tough-Pitch Coppers								
ETP	Electrolytic tough-pitch	C11000	×	×	×	×	×	×	×	×
RHC	Remelted, high-conductivity tough pitch	C11010	×	×	×	×	×	×	×	×
ETP	Electrolytic tough-pitch (anneal resist)	C11100	×	×	×		×	×	×	×
CRTP	Chemically refined tough-pitch	C11030	×	×	×	×	×	×	×	×
FRHC	Fire-refined, high-conductivity tough-pitch	C11020	×	×	×	×	×	×	×	×
ETP[F]	Silver-bearing, tough-pitch	C11300, C11400, C11500, C11600	×	×	×	×	×	×	×	×
FRTP	Fire-refined, tough-pitch	C12500		×	×	×	×	×	×	×
FRSTP	Fire-refined tough-pitch with silver	C12700, C12800, C12900, C1300		×	×	×	×			×
		Oxygen-Free Coppers (Without use of Deoxidants)								
OFE	Oxygen-free, electronic	C10100	×	×	×		×	×	×	×
OF	Oxygen-free	C10200	×	×	×		×	×	×	×
OFS	Oxygen-free, silver-bearing	C10400, C10500, C10700	×	×	×		×	×	×	×
OFXLP	Oxygen-free, extra low phosphorus	C10300	×	×	×		×	×	×	×
OFLP	Oxygen-free, low-phosphorus	C10800	×	×	×		×	×	×	×
		Deoxidized Coppers								
DLP	Phosphorized, low-residual phosphorus	C12000		×	×		×	×	×	×
DLPS[G]	Phosphorized, low-residual phosphorus silver-bearing	C12100		×	×		×	×	×	×
DHP[H]	Phosphorized, high-residual phosphorus	C12200		×	×		×	×	×	×
DHPS[G]	Phosphorized, high-residual phosphorus silver-bearing	C12300		×	×		×	×	×	×
DPA	Phosphorized, arsenic-bearing	C14200		×			×	×		
DPTE[I]	Phosphorized, tellurium-bearing	C14500		×					×	
		Other Coppers								
	Sulfur-bearing	C14700		×					×	
	Zirconium-bearing	C15000		×	×		×		×	

TABLE A1 *Continued*

[A] See Appendix A2.
[B] The chemical compositions associated with these numbers are listed in the product specifications and in the Standard Designations for Copper and Copper Alloys that appear in this publication under "Related Material".
[C] The "X" in the table indicates commercial availability.
[D] See Appendix A3.
[E] See Appendix A4.
[F] This includes Types ETP, CRTP, and FRHC coppers to which silver has been added in amounts agreed upon.
[G] This includes oxygen-free copper to which phosphorus and silver have been added in amounts agreed upon.
[H] This includes oxygen-free copper to which phosphorus has been added.
[I] This includes oxygen-free tellurium-bearing copper to which phosphorus has been added in amounts agreed upon.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B283: Standard Specification for Copper and Copper-Alloy Die Forgings (Hot-Pressed)

CFR Section(s): 46 CFR 56.60-2

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 283 – 96

Standard Specification for Copper and Copper-Alloy Die Forgings (Hot-Pressed)[1]

This standard is issued under the fixed designation B 283; 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 specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope*

1.1 This specification covers the requirements for copper and copper alloy die forgings produced by the hot pressing method. The following copper and copper alloys are included:

Copper or Copper Alloy UNS No.	Name
C11000	copper
C14500	copper-tellurium
C14700	copper-sulfur
C36500	leaded Muntz metal
C37700	forging brass
C46400	naval brass
C48200	medium leaded naval brass
C48500	leaded naval brass
C61900	aluminum bronze
C62300	aluminum bronze, 9 %
C63000	aluminum-nickel bronze
C63200	aluminum-nickel bronze
C64200	aluminum-silicon bronze
C64210	aluminum-silicon bronze, 6.7 %
C65500	high-silicon bronze (A)
C67500	manganese bronze (A)
C67600	...
C77400	nickel silver, 45-10

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only.

1.3 The following safety caveat pertains only to Section 10 of this specification: *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.*

NOTE 1—Nominal composition and relative forgeability ratings are given in Appendix X1.

2. Referenced Documents

2.1 *ASTM Standards:*

B 249 Specification for General Requirements for Wrought Copper and Copper Alloy Rod, Bar, Shapes and Forgings[2]

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[2]

B 846 Terminology for Copper and Copper Alloys[2]

E 8 Test Methods for Tension Testing of Metallic Materials[3]

E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes[4]

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Method)[4]

E 76 Test Method for Chemical Analysis of Nickel-Copper Alloys[4]

E 478 Test Methods for Chemical Analysis of Copper Alloys[4]

2.2 *ISO Standard:*

7602 Determination of Tellurium Content (High Content)—Flame Atomic Absorption Spectrometric Method[5]

3. General Requirements

3.1 The following sections of Specification B 249 are a part of this specification:

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

3.1.15 In addition, when a section with a title identical to one of those referenced in 3.1 appears in this specification, it contains additional requirements that supplement those appearing in Specification B 249.

4. Terminology

4.1 *Definitions:*

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.02 on Rod, Bar, Wire, Shapes, and Forgings.

Current edition approved Sept. 10, 1996. Published December 1996. Originally published as B 283 – 53 T. Last previous edition B 283 – 94.

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

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

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

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

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

4.1.1 For definition of terms related to copper and copper alloys refer to Terminology B 846.

4.2 *Definition of Term Specific to This Standard:*

4.2.1 *hot pressed forging, n*—a product made by pressing a heated blank or section of wrought copper or copper alloy in a closed impression die.

5. Ordering Information

5.1 Orders for product to this specification should include the following information:

5.1.1 ASTM designation and year of issue,

5.1.2 Copper or Copper Alloy UNS No. designation (Section 1),

5.1.3 Drawing showing the shape dimensions and tolerances (Section 11),

5.1.4 Temper (Section 8),

5.1.5 Quantity; total weight or number of pieces for each form, temper and copper or copper alloy,

5.1.6 When product is purchased for agencies of the U.S. Government (Section 12), and

5.1.7 When product must adhere to the requirements of ASME Boiler and Pressure Vessel Code (Section 9).

5.2 The following options are available under this specification and should be included in the contract or purchase order when required:

5.2.1 Certification (Section 14 and Supplementary Requirements), and

5.2.2 Mill Test Report (Specification B 249).

6. Material and Manufacture

6.1 *Materials:*

6.1.1 The starting material shall be rods, billets or blanks cut from cast or wrought material of one of the copper or copper alloys listed in Section 1.1 of this specification.

6.2 *Manufacture:*

6.2.1 The product shall be manufactured by hot pressing between the upper and lower sections of a set of dies into which cavities have been formed to the configuration defined by the purchaser's submitted drawings.

6.2.2 Product of Copper Alloy UNS No. C 63200 shall be heat treated (Section 10).

7. Chemical Composition

7.1 The materials shall conform to the requirements specified in Table 1 for the Copper or Copper Alloy UNS No. designated in the ordering information.

7.2 These composition limits do not preclude the presence of other elements when limits for unnamed elements are required, they shall be established by agreement between manufacturer or supplier and the purchaser.

7.2.1 For copper alloys in which zinc is specified as a remainder, either copper or zinc is permitted to be taken as the difference between the sum of results for all the elements analyzed and 100 %. When copper is so determined, that difference value shall conform to the requirements given in Table 1.

7.2.2 For copper alloys for which copper is specified as the remainder, copper may be taken as the difference between the sum of all the elements analyzed and 100 %.

7.3 When all the elements in Table 1 are determined for the individual alloy, the sum of results shall be 99.6 % min for Copper Alloy UNS No. C36500, C46400, C48200, C48500 and 99.5 % for all others.

8. Temper

8.1 Tempers, as defined in Practice B 601, available under this specification are M10 (as hot forged-air cooled), M11 (as forged-quenched) and TQ50 (quench hardened and temper annealed).

9. Mechanical Property Requirements

9.1 Mechanical property requirements are subject to agreement between the manufacturer and the purchaser.

9.2 Product specified to meet the requirements of the *ASME Boiler and Pressure Vessel Code* shall have tensile properties as prescribed in Table 2 when tested in accordance with Test Methods E 8.

10. Heat Treatment

10.1 Product produced from Copper Alloy UNS No. C63200 shall be heat treated as follows:

10.1.1 Heat to 1550°F (843°C) minimum for 1 h minimum and quench in water or other suitable medium.

10.1.2 Temper at 1300+ and −25°F (704+ and −14°C) for 3 to 9 hrs as required to meet mechanical properties.

11. Purchases for U.S. Government

11.1 Product purchased for agencies of the U.S. Government shall conform to the additional requirements prescribed in the Supplementary Requirements section of this specification.

12. Dimensions and Permissible Variations

12.1 The dimensions and tolerances for forgings shall be those agreed upon between the manufacturer and the purchaser and such dimensions and tolerances shall be specified on the drawings which form a part of the contract or purchase order.

NOTE 2—Typical tolerances commonly used for forgings are shown in Appendix X2 (Table X2.1).

13. Test Methods

13.1 *Chemical Analysis:*

13.1.1 Chemical composition shall, in case of disagreement, be determined as follows:

Element		ASTM Test Method
Aluminum		E 478
Arsenic		E 62
Copper		E 478
Iron	<1.3 %	E 478
	>1.3 %	E 54
Lead		E 478 (AA)
Manganese		E 62
Nickel	<5 %	E 478 (Photometric)
	>5 %	E 478 (Gravimetric)
Phosphorus		E 62
Silicon		E 54 (Perchloric Acid)
Tin	<1.3 %	E 478
	>1.3 %	E 54
Zinc	<2 %	E 478 (AA)
	>2 %	E 478 (Titrimetric)
		ISO Test Method
Tellurium		7602

NOTE—< = less than; > = greater than

13.1.2 Test method(s) to be followed for the determination of element(s) required by contractual or purchase order

TABLE 1 Chemical Requirements

Copper or Copper Alloy UNS No.	Composition, %												
	Copper	Lead	Tin	Iron	Nickel (incl Co)	Aluminum	Silicon	Manganese	Zinc	Sulfur	Tellurium	Phosphorus	Arsenic
C 11000	99.90[A] min	...	...	...	...	...	...	...	...	...	...	...	...
C 14500[B]	99.90[C] min	...	...	...	...	...	...	...	...	...	0.40–0.7	0.004–0.012[D]	...
C 14700[B]	99.90[E] min	...	...	...	...	...	...	...	...	0.20–0.50	...	0.002–0.005[D]	...
C 36500	58.0–61.0	0.25–0.7	0.25 max	0.15 max	...	...	...	...	remainder	...	...	...	...
C 37700	58.0–61.0	1.5–2.5	...	0.30 max	...	...	...	...	remainder	...	...	...	...
C 46400	59.0–62.0	0.20 max	0.5–1.0	0.15 max	...	...	...	...	remainder	...	...	...	...
C 48200	59.0–62.0	0.40–1.0	0.50–1.0	0.15 max	...	...	...	...	remainder	...	...	...	...
C 48500	59.0–62.0	1.3–2.2	0.5–1.0	0.15 max	...	...	...	...	remainder	...	...	...	...
C 61900	remainder	0.02 max	0.6 max	3.0–4.5[F]	...	8.5–10.00	...	...	0.8 max	...	...	...	...
C 62300	remainder	...	0.6 max	2.0–4.0	1.0 max	8.5–11.0[G]	0.25 max	0.50 max	...	...	...	...	...
C 63000	remainder	...	0.20 max	2.0–4.0	4.0–5.5	9.0–11.0	0.25 max	1.5 max	0.30 max	...	...	...	...
C 63200	remainder	0.02 max	...	3.5–4.3[H]	4.0–4.8	8.7–9.5	0.10 max	1.2–2.0	...	...	...	...	...
C 64200	remainder	0.05 max	0.20 max	0.30 max	0.25 max	6.3–7.6	1.5–2.2	0.10 max	0.50 max	...	...	...	0.15 max
C 64210	remainder	0.05 max	0.20 max	0.30 max	0.25 max	6.3–7.0	1.50–2.0	0.10 max	0.50 max	...	...	...	0.15 max
C 65500	remainder	0.05 max	...	0.8 max	0.6 max	...	2.8–3.8	0.50–1.3	1.5 max	...	...	...	...
C 67500	57.0–60.0	0.20 max	0.5–1.5	0.8–2.0	...	0.25 max	...	0.05–0.5	remainder	...	...	...	...
C 67600	57.0–60.0	0.5–1.0	0.5–1.0	0.4–1.3	...	...	...	0.05–0.5	remainder	...	...	...	...
C 77400	43.0–47.0	0.20 max	...	...	9.0–11.0	...	...	...	remainder	...	...	...	...

[A] Silver counting as copper.
[B] Includes oxygen-free or deoxidized grades with deoxidizers (such as phosphorus, boron, lithium, or others) in amount agreed upon.
[C] This includes copper plus silver plus tellurium.
[D] Other deoxidizers may be used as agreed upon, in which case phosphorus need not be present.
[E] This includes copper plus silver plus sulfur plus phosphorus.
[F] For boiler code application maximum iron content shall be 4.0 %
[G] For boiler code application maximum aluminum content shall be 10.0 %.
[H] Iron content shall not exceed nickel content.

TABLE 2 Tensile Requirements

Diameter or Section Thickness, in. (mm)	Tensile Strength, min		Yield Strength at 0.5% Extension Under Load, min		Elongation in 4 × Diameter or Thickness of Specimen, min, %
	ksi	MPa[A]	ksi	MPa[A]	
	Copper Alloy UNS No. C 37700				
Up to 1½ (38.1), incl	50	345	18	124	25
Over 1½ (38.1)	46	317	15	103	30
	Copper Alloy UNS No. C 64200				
Up to 1½ (38.1), incl	70	483	25	172	30
Over 1½ (38.1)	68	469	23	156	35
	Copper Alloy UNS Nos. C 46400, C 48200 and C 48500				
All Sizes	52	358	22	152	25

[A] See Appendix X3.

agreement shall be as agreed upon between the supplier and the purchaser.

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	nearest unit in the last right-hand place of figures
Tensile strength, Yield strength	nearest ksi, nearest 5 MPa for over 10 to 100 ksi, incl
Elongation	nearest 1 %

14. Certification

14.1 Certification to this specification is mandatory for product purchased for *ASME Boiler and Pressure Vessel* applications.

15. Keywords

15.1 copper and copper alloy die forgings (hot pressed); die forgings (hot pressed)

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract or order, for agencies of the U.S. Government.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

S1.1.1 *Federal Standards:*[6]

Fed. Std. No. 102 Preservation, Packaging and Packing Levels

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 185 Identification Marking of Copper and Copper-Base Alloy Mill Products

S1.1.2 *Military Standards:*[6]

MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-129 Marking for Shipment and Storage

S1.1.3 *Military Specification:*[6]

MIL-C-3993 Packaging of Copper and Copper-Base Alloy Mill Products

S2. Quality Assurance

S2.1 *Responsibility for Inspection:*

S2.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

S3. Identification Marking

S3.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 185 except that the ASTM specification number and the alloy number shall be used.

S4. Preparation for Delivery

S4.1 *Preservation, Packaging, Packing:*

S4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade or class and shall be preserved and packaged, Level A or C, packed Level A, B, or C as specified in the contract or purchase order, in accordance with the requirements of MIL-C-3993.

S4.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

[6] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, ATTN: NPODS.

APPENDIXES

(Nonmandatory Information)

X1. NOMINAL COMPOSITION AND RELATIVE FORGEABILITY RATINGS

X1.1 The nominal composition of the various forging materials are shown in Table X1.1.

TABLE X1.1 Nominal Compositions and Forgeability Ratings

Copper or Copper Alloy UNS No.	Nominal Composition, %											Forgeability Rating[A]
	Copper	Lead	Tin	Iron	Nickel	Aluminum	Silicon	Manganese	Zinc	Sulfur	Tellurium	
C 11000	100	...	...	...	...	...	...	...	...	...	...	65
C 14500	99.45	...	...	...	...	...	...	...	...	...	0.55	65
C 14700	99.5	...	...	...	...	...	...	...	...	0.35	...	65
C 36500	60	0.6	...	...	...	...	...	...	39.4	...	...	...
C 37700	60	2	...	...	...	...	...	...	38	...	...	100
C 46400	60	...	0.8	...	...	...	...	...	39.2	...	...	90
C 48200	60	0.7	0.8	...	...	...	...	...	38.5	...	...	...
C 48500	60	1.8	0.8	...	...	...	...	...	37.4	...	...	90
C 61900	87.5	...	...	3.5	...	9	...	...	...	...	...	75
C 62300	88	...	...	3	...	9	...	...	...	...	...	75
C 63000	81	...	...	3	5	10	...	1	...	...	...	75
C 63200	81	...	...	4	4.5	9	...	1.5	...	...	...	75
C 64200	91	...	...	...	...	7	2	...	...	...	...	75
C 64210	91.3	...	...	...	...	6.7	2	...	...	...	....	75
C 65500	96	...	...	[B]	...	...	3	[B]	[B]	...	...	40
C 67500	58.5	...	1	1	...	...	...	0.10	39.4	...	...	80
C 67600	58.5	0.75	1	0.8	...	...	...	0.10	39.6	...	...	80
C 77400	45	...	...	...	10	...	...	...	45	...	...	85

[A] Relative forgeability rating takes into consideration such variable factors as pressure, die wear, and plasticity (hot). Since it is impracticable to reduce these variables to common units, calibration in terms of a percentage of the most generally used alloy, forging brass (100 %), is considered the most practical basis for such ratings. The values shown represent the general opinion and are intended for information to enable the designer to better understand the forging characteristics of these various alloys. Intricate parts are more likely to be available in alloys having a high rating.

[B] One or more of these elements may be present as specified in Table 2.

X2. DIMENSIONAL TOLERANCES

X2.1 The data in Table X2.1 do not constitute a part of this specification. They are given merely to indicate to the purchaser the various forging types and some dimensional tolerances used on commercially designed hot-pressed forgings up to 2 lb (0.91 kg) in weight. For tolerances applicable to heavier forgings, the manufacturers should be consulted.

TABLE X2.1 Dimensional Tolerances

	Tolerances, plus and minus, in. (mm) Except as Indicated[A]			
	Copper or Copper Alloy UNS Nos.			
	C 11000 C 14500 C 14700 C 61900 C 62300 C 64200 C 64210	C 36500 C 37700 C 46400 C 48200 C 48500 C 67500 C 67600	C 77400	C 63000 C 63200 C 65500
Forging types:				
Solid	0.010 (0.25)	0.008 (0.20)	0.008 (0.20)	0.012 (0.30)
Solid, with symmetrical cavity	0.010 (0.25)	0.008 (0.20)	0.008 (0.20)	0.012 (0.30)
Solid, with eccentric cavity	0.012 (0.30)	0.008 (0.20)	0.008 (0.20)	0.012 (0.30)
Solid, deep extrusion	0.012 (0.30)	0.010 (0.25)	0.010 (0.25)	0.014 (0.36)
Hollow, deep extrusion	0.012 (0.30)	0.010 (0.25)	0.010 (0.25)	0.014 (0.36)
Thin section, short (up to 6 in. (152 mm) incl.)	0.012 (0.30)	0.010 (0.25)	0.010 (0.25)	0.014 (0.36)
Thin section, long (over 6 in. (152 mm) to 14 in. (356 mm) incl.)	0.015 (0.38)	0.015 (0.38)	0.015 (0.38)	0.020 (0.51)
Thin section, round	0.012 (0.30)	0.010 (0.25)	0.010 (0.25)	0.014 (0.36)
Draft angles, outside and inside 1 to 5°	½°	½°	½°	½°
Machining allowance (on one surface)	1/32 (0.79)	1/32 (0.79)	1/32 (0.79)	1/32 (0.79)
Flatness (maximum deviation per inch)	0.005 (0.13)	0.005 (0.13)	0.005 (0.13)	0.005 (0.13)
Concentricity (total indicator reading)	0.030 (0.76)	0.020 (0.51)	0.030 (0.76)	0.030 (0.76)
Nominal web thickness:	5/32 (4.0)	1/8 (3.2)	1/8 (3.2)	3/16 (4.8)
Tolerance	1/64 (0.40)	1/64 (0.40)	1/64 (0.40)	1/64 (0.40)
Nominal fillet and radius:	3/32 (2.4)	1/16 (1.6)	1/16 (1.6)	1/8 (3.2)
Tolerance	1/64 (0.40)	1/64 (0.40)	1/64 (0.40)	1/64 (0.40)
Approximate flash thickness	1/16 (1.6)	3/64 (1.2)	3/64 (1.2)	5/64 (2.0)

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

X3. TYPICAL MECHANICAL PROPERTIES

X3.1 Mechanical properties of any forging are influenced by shape and size. Unless otherwise specified in the purchase order or specifically guaranteed by the manufacturer, acceptance of forgings under this specification shall not depend on the mechanical properties determined by tension or hardness tests. (Frequently, the design of forgings will not permit adequate test sections.) Therefore, the data in Table X3.1 do not constitute a part of this specification, and are given for general information only. They are typical of forgings up to 2 lb (0.91 kg) in weight.

TABLE X3.1 Typical Mechanical Properties of Forgings as Hot Pressed, Temper M10, M11, or TQ50[C]

Copper or Copper Alloy UNS No.	0.505-in. (128-mm) Diameter Test Section					Rockwell Hardness (Filed Surface, 1/8-in. (3.18-mm) chord, min)	
	Tensile Strength		Yield Strength (0.5 % Extension Under Load)		Elongation in 4 × Diameter, %	F Scale	B Scale
	ksi[A]	MPa[B]	ksi[A]	MPa[B]			
C 11000	33	230	11	75	40	37	...
C 14500	34	235	12	85	35	40	...
C 14700	34	235	12	85	35	40	...
C 36500	58	400	23	160	40	...	45
C 37700	58	400	23	160	40	...	45
C 46400	64	440	26	180	40	...	55
C 48200	64	440	26	180	40	...	55
C 48500	62	425	24	165	40	...	55
C 61900	82	565	37	255	32	...	82
C 62300	82	565	37	255	32	...	82
C 63000	95	655	48	330	15	...	90
C 63200	92	635	45	310	18	...	88
C 64200	83	570	41	285	35	...	77
C 64210	83	570	41	285	35	...	77
C 65500	52	360	18	125	70	...	62
C 67500	72	495	34	235	33	...	69
C 67600	72	495	34	235	33	...	69
C 77400	83	570	36	250	25	...	73

[A] ksi = 1000 psi.
[B] See Appendix X4.
[C] For Copper Alloy UNS Nos. C 63000 and C 63200.

X4. METRIC EQUIVALENTS

X4.1 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.

SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification that have been incorporated since the 1994 issue as follows:

(1) Scope: Revised and safety caveat added as required.
(2) General Requirements: A new section which enables the specification to utilize Specification B 249. This is a new section.
(3) Terminology: Revised to reference Terminology B 846.
(4) Ordering Information: Reorganized and expanded for greater clarity.
(5) Material and Manufacture: Revised to better define material.
(6) Chemical composition: Revised.
(7) Mechanical Property Requirements: Revised for greater clarity.
(8) Heat Treatment: A new section. Information previously in the Materials and Manufacture section.
(9) Test Methods: Individual test methods identified.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B315: Seamless Copper Alloy Pipe Tube

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THE EXECUTIVE DIRECTOR
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WASHINGTON, D.C.

Designation: B 315 – 93

Standard Specification for Seamless Copper Alloy Pipe and Tube[1]

This standard is issued under the fixed designation B 315; 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 specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification[2] covers seamless copper alloy pipe in nominal or standard pipe sizes, both regular and extra-strong, and seamless tube in straight lengths for general engineering purposes. Pipe and tube are commercially available in the following alloys:

Copper Alloy UNS No.[3]	Previously Used Designation
C61300	...
C61400	Aluminum Bronze D
C63020	...
C65100	Low-Silicon Bronze B
C65500	High-Silicon Bronze A

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given 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 referenced herein:

2.1.1 *ASTM Standards:*

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[4]

E 8 Test Methods of Tension Testing of Metallic Materials[5]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[5]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[6]

E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes[7]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[7]

E 243 Practice for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes[8]

E 527 Practice for Numbering Metals and Alloys (UNS)[9]

3. Terminology

3.1 *Definitions:*

3.1.1 *tube*—a hollow product of round or any other cross section having a continuous periphery.

3.1.1.1 *tube, seamless*—a tube produced with a continuous periphery in all stages of the operations.

3.1.1.2 *pipe*—a seamless tube conforming to the particular dimensions commercially known as Nominal or Standard Pipe Sizes.

3.1.2 *average diameter (for round tubes only)*—the average of the maximum and minimum outside diameters, or maximum and minimum inside diameters, whichever is applicable, as determined at any one cross section of the tube.

3.1.3 *lengths*—straight pieces of the product.

3.1.3.1 *ends*—straight pieces, shorter than the nominal length, left over after cutting the product into mill lengths, stock lengths, or specific lengths. They are subject to minimum length and maximum weight requirements.

3.1.3.2 *specific*—straight lengths that are uniform in length, as specified, and subject to established length tolerances.

3.1.3.3 *specific with ends*—specific lengths, including ends.

3.1.3.4 *stock*—straight lengths that are mill cut and stored in advance of orders. They are usually 10, 12, or 20 ft (3.05, 3.66, or 6.10 m) and subject to established length tolerances.

3.1.3.5 *stock with ends*—stock lengths, including ends.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *capable of*—as used in this specification, means that the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Alloy (Section 6, Table 1),

4.1.2 Temper (Section 7),

4.1.3 Pipe size (regular or extra-strong) (see 10.2), or tube

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.04 on Pipe and Tube.

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[2] For *ASME Boiler and Pressure Vessel Code* applications see related Specification SB-315 in Section II of that Code.

[3] 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.

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

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

[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 03.03.

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

TABLE 1 Chemical Requirements

Copper Alloy UNS No.	C61300[B]	C61400	C63020[C]	C65100	C65500
	Composition, % Max (Unless Shown as a Range or Minimum)				
Copper[A]	remainder	remainder	74.5 min	remainder	remainder
Lead	0.01	0.01	0.03	0.05	0.05
Iron	2.0–3.0	1.5–3.5	4.0–5.5	0.8	0.8
Zinc	0.10	0.20	0.30	1.5	1.5
Aluminum	6.0–7.5	6.0–8.0	10.5–11.5	...	...
Manganese	0.20	1.0	1.5	0.7	0.50–1.3
Silicon	0.10	...	...	0.8–2.0	2.8–3.8
Tin	0.20–0.50	...	0.25	...	...
Nickel (including cobalt)	0.15	...	4.2–6.0	...	0.6
Phosphorus	0.015	0.015	...	...	...

[A] Including silver.
[B] When the product is for subsequent welding applications and is so specified by the purchaser, chromium shall be 0.05 % max, cadmium 0.05 % max, zinc 0.05 % max, and zirconium 0.05 % max.
[C] Chromium shall be 0.05 max and cobalt 0.20 max.

TABLE 2 Tensile Requirements

Copper Alloy UNS No.	C61300 and C61400	C63020	C65100		C65500
Temper Designation	M30 (Extruded) or O61 (Annealed)	TQ30 (Quench Hardened and Tempered)	O61 (Annealed)	H80 (Hard Drawn)	O61 (Annealed)
Tensile strength, min, ksi[A] (MPa)[B]	65 (447)	130 (896)	40 (275)	50 (345)	50 (345)
Yield strength at 0.5 % extension under load, ksi[A] (MPa)[B]	28 (193) min	89 (621)[C]	10 (69) min	40 (275) min	15 to 29 (103 to 200)
Elongation in 2 in. or 50 mm, min, %	30	6	35	7	35

[A] ksi = 1000 psi.
[B] See appendix.
[C] Yield Strength at 0.2 % offset, min, ksi[A] (MPa).[B]

dimensions (diameter and wall thickness) (see 10.3 and 10.4),

4.1.4 Length (see 10.5),

4.1.5 Total length of each size,

4.1.6 Whether the product is to be subsequently welded (see Table 1 and Footnote B),

4.1.7 Finish (see 11.2 and 11.3), and

4.1.8 When Copper Alloy UNS No. C63020 is ordered under this specification, tube diameter, wall thickness and length, sizes, and tolerances shall be a part of the purchase order as agreed upon between the supplier and the purchaser.

4.2 In the case of material to be used for welding or brazing, orders shall specify "Specially Cleaned."

5. Materials and Manufacture

5.1 The material shall be of such quality and purity that the finished product shall have the properties and characteristics prescribed in this specification.

5.2 The material shall be produced by either hot- or cold-working operations, or both. It shall be finished, unless otherwise specified, by such cold working and annealing or heat treatment as may be necessary to meet the properties specified.

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 the manufacturer or supplier and the purchaser.

6.2.1 For copper alloys in which copper is specified as the remainder, copper may be taken as the difference between the sum of all the elements analyzed and 100 %.

6.2.1.1 When all the elements in Table 1 are analyzed, their sum shall be as shown in the following table.

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C61300	99.8
C61400	99.5
C63020	99.5
C65100	99.5
C65500	99.5

7. Temper

7.1 Tempers available under this specification and as prescribed in Practice B 601 are as follows: Copper Alloy UNS Nos. C61300 and C61400 shall be furnished in the hot-extruded (M30), hot-extruded and annealed (O30), or cold-worked and annealed (O61) condition. Copper Alloy UNS No. C63020 shall be furnished in the quench hardened and temperd (TQ30) condition to a hardness of 26 HRC minimum (see Test Method E 18). Copper Alloy UNS No. C65500 shall be furnished in the extruded and annealed (O30), or cold-worked and annealed condition (O61). Copper Alloy UNS No. C65100 shall be furnished in the extruded and annealed (O30), extruded and cold-worked (H50), or cold-worked and annealed condition (O61). Copper Alloy UNS Nos. C65100 and C65500, which are supplied in the cold-worked and annealed condition (O61) shall show complete recrystallization.

7.2 Copper Alloy UNS No. C63020 tube shall be quench hardened and tempered (TQ30) as follows:

7.2.1 Heat to 1550 to 1650°F for 2-h minimum and quench in water.

7.2.2 Temper at 900 to 1000°F for 2–h minimum and air cool to room temperature.

8. Tensile Properties

8.1 The material shall conform to the requirements of Table 2 as the tensile properties.

9. Nondestructive Testing

9.1 The pipe or tube may be tested, in the final drawn, annealed, or specified temper or in the drawn temper prior to the final anneal, unless otherwise agreed upon between the supplier and the purchaser. Unless otherwise specified, the manufacturer shall have the option of testing the pipe or tube by one of the following tests:

9.1.1 *Eddy-Current Test*—Each tube, and each pipe in nominal or standard sizes from ⅛ in. up to and including 2½ in. regular and extra strong, shall be subjected to an eddy-current test. Testings shall follow the procedures of Practice E 243 except for the determination of "end effect." The pipe or tube shall be passed through an eddy-current testing unit adjusted to provide information on the suitability of each piece for the intended application.

9.1.1.1 Notch-depth standards, rounded to the nearest 0.001 in. (0.025 mm) shall be 10 % of the wall thickness. Notch-depth tolerances shall be ±0.0005 in. (0.013 mm). Alternatively, when a manufacturer uses speed-insensitive equipment that can select a maximum unbalance signal, a maximum unbalance signal of 0.3 % may be used.

9.1.1.2 Pipes or tubes that do not activate the signalling device of the eddy-current tester shall be considered as conforming to the requirements of this test. Lengths with discontinuities indicated by the testing unit may, at the option of the manufacturer, be reexamined or retested to determine whether the discontinuity is cause for rejection. Signals that are found to have been caused by minor mechanical damage, soil, or moisture shall not be cause for rejection provided the pipe or tube dimensions are still within the prescribed limits and the pipe or tube is suitable for its intended application.

9.1.2 *Pressure Tests*—Each pipe or tube selected in accordance with 13.3 shall withstand the pressure test of 9.1.2.1 or 9.1.2.2

9.1.2.1 *Hydrostatic Test*—Each pipe or tube shall stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 7000 psi (48 MPa), determined by the following equation for thin hollow cylinders under tension. The pipe or tube need not be tested at a hydrostatic pressure of over 1000 psi (6.9 MPa) unless so specified. At the option of the manufacturer, annealed pipe with wall thickness up to 0.083 in. (2.11 mm) inclusive may be tested in the drawn condition, prior to annealing.

$$P = 2St/(D - 0.8t)$$

where:

P = hydrostatic pressure, psi (MPa),
t = thickness of pipe or tube wall, in. (mm),
D = outside diameter of the pipe or tube, in. (mm), and
S = allowable fiber stress of the material, psi (MPa).

9.1.2.2 *Pneumatic Test*—Each pipe or tube shall stand an internal air pressure of 60 psi (415 kPa), min., for 5 s without showing evidence of leakage. The test method used shall permit easy visual detection of any leakage, such as by having the tube under water or by pressure differential method.

10. Dimensions, Weights, and Permissible Variations

10.1 *General:*

10.1.1 The standard method of specifying wall thickness shall be in decimal fractions of an inch.

10.1.2 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.

10.1.3 Tolerances on a given tube may be specified with respect to any two, but not all three, of the following: outside diameter, inside diameter, wall thickness.

NOTE—Blank spaces in the tolerance tables indicate either that the material is not generally available or that no tolerances have been established.

10.2 *Dimensions*—Dimensions and theoretical weights of nominal or standard pipe sizes shall be in accordance with Table 3.

10.3 *Wall Thickness Tolerances*—Wall thickness tolerances for pipe shall be in accordance with Tables 4 and 5. Wall thickness tolerances for tube shall be in accordance with Tables 6, 7, and 8.

10.4 *Diameter Tolerances*—Diameter tolerances for pipe shall be as follows:

10.4.1 *Nominal or Standard Pipe Size 1½ in. and Under*—+0.016, −0.031 in. (+0.40, −0.79 mm).

10.4.2 *Nominal or Standard Pipe Size over 1½ in.*—±1 % of specified diameter.

10.4.3 The dimensional limits of nominal or standard pipe sizes are shown in Tables 4 and 5.

10.4.4 Diameter tolerances for tube shall be in accordance with Table 9.

10.5 *Length Tolerances:*

10.5.1 Length tolerances shall be in accordance with Table 10.

10.5.2 *Schedule of Tube Lengths*—Specific and stock lengths with ends shall be in accordance with Table 11.

10.6 *Squareness of Cut*—For pipe and tube in straight lengths, the departure from squareness of the end of any pipe or tube shall not exceed the following:

10.6.1 *Pipe:*

Outside Diameter, in. (mm)	Tolerance
Up to ⅝ (15.9) incl	0.010 in. (0.25 mm)
Over ⅝ (15.9)	0.016 in./in. (0.016 mm/mm) of diameter

10.6.2 *Tube:*

Outside Diameter, in. (mm)	Tolerance
Up to ⅝ (15.9) incl	0.010 in. (0.25 mm)
Over ⅝ (15.9)	0.016 in./in. (0.016 mm/mm) of diameter

10.7 The density of the materials covered by this specification shall be taken to be as follows:

Copper Alloy UNS No.	Density, lb/in.³ (g/cm³)
C61300	0.285 (7.89)
C61400	0.285 (7.89)
C63020	0.269 (7.45)
C65100	0.316 (8.78)
C65500	0.308 (8.53)

TABLE 3 Dimensions and Weights of Copper Alloy Pipe, Standard Pipe Sizes

Nominal or Standard Pipe Size, in.	Dimension, in. (mm)			Cross-Section Area of Bore, in.² (cm²)	Theoretical Weight, lb/ft (kg/m)		
	Outside Diameter	Inside Diameter	Wall Thickness		Copper Alloy UNS No.		
					C61300 and C61400	C65500	C65100
			Regular				
⅛	0.405 (10.3)	0.269 (6.83)	0.068 (1.73)	0.057 (0.367)	0.246 (0.366)	0.266 (0.395)	0.273 (0.406)
¼	0.540 (13.7)	0.364 (9.25)	0.088 (2.24)	0.104 (0.670)	0.427 (0.634)	0.462 (0.686)	0.474 (0.704)
⅜	0.675 (17.1)	0.493 (12.5)	0.091 (2.31)	0.191 (1.23)	0.571 (0.849)	0.617 (0.917)	0.633 (0.941)
½	0.840 (21.3)	0.622 (15.8)	0.109 (2.77)	0.304 (1.96)	0.856 (1.27)	0.925 (1.37)	0.949 (1.41)
¾	1.050 (26.7)	0.824 (20.9)	0.113 (2.87)	0.533 (3.44)	1.14 (1.69)	1.23 (1.83)	1.26 (1.88)
1	1.315 (33.4)	1.049 (26.6)	0.133 (3.38)	0.864 (3.57)	1.69 (2.51)	1.83 (2.72)	1.87 (2.79)
1¼	1.660 (42.2)	1.380 (35.1)	0.140 (3.56)	1.496 (9.66)	2.29 (3.40)	2.47 (3.68)	2.53 (3.77)
1½	1.900 (48.3)	1.610 (40.9)	0.145 (3.68)	2.036 (13.1)	2.74 (4.07)	2.95 (4.40)	3.03 (4.51)
2	2.375 (60.3)	2.067 (52.5)	0.154 (3.91)	3.356 (21.7)	3.67 (5.45)	3.97 (5.91)	4.07 (6.06)
2½	2.875 (73.0)	2.469 (62.7)	0.203 (5.16)	4.788 (30.9)	5.83 (8.66)	6.30 (9.37)	6.46 (9.61)
3	3.500 (88.9)	3.068 (77.9)	0.216 (5.49)	7.393 (47.7)	7.62 (11.3)	8.24 (12.3)	8.45 (12.6)
3½	4.000 (102)†	3.548 (90.1)	0.226 (5.74)	9.887 (63.8)	9.16 (13.6)	9.90 (14.7)	10.2 (15.1)
4	4.500 (114)	4.026 (102)	0.237 (6.02)	12.730 (82.1)	10.9 (16.2)	11.7 (17.5)	12.0 (17.9)
5	5.562 (141)	5.046 (128)	0.258 (6.55)	19.998 (129)	14.7 (21.8)	15.9 (23.6)	16.3 (24.3)
6	6.625 (168)	6.065 (154)	0.280 (7.11)	28.890 (186)	19.1 (28.4)	20.6 (30.7)	21.2 (31.5)
8	8.625 (219)	7.981 (203)	0.322 (8.18)	50.030 (323)	28.7 (42.7)	31.0 (46.2)	31.9 (47.4)
10	10.750 (273)	10.020 (255)	0.365 (9.27)	78.8 (508)	40.8 (90.1)	44.1 (65.6)	45.2 (67.3)
12	12.750 (324)	12.000 (305)	0.375 (9.52)	113.0 (729)	49.9 (74.1)	53.9 (80.2)	55.3 (82.3)
			Extra Strong				
⅛	0.405 (10.3)	0.215 (5.46)	0.095 (2.41)	0.036 (0.232)	0.316 (0.470)	0.342 (0.508)	0.351 (0.522)
¼	0.540 (13.7)	0.302 (7.67)	0.119 (3.02)	0.072 (0.464)	0.538 (0.799)	0.582 (0.865)	0.597 (0.887)
⅜	0.675 (17.1)	0.423 (10.7)	0.126 (3.20)	0.141 (0.909)	0.743 (1.10)	0.803 (1.19)	0.824 (1.22)
½	0.840 (21.3)	0.546 (13.9)	0.147 (3.73)	0.234 (1.51)	1.10 (1.63)	1.183 (1.76)	1.214 (1.80)
¾	1.050 (26.7)	0.742 (18.8)	0.154 (3.91)	0.432 (2.79)	1.48 (2.20)	1.60 (2.39)	1.65 (2.45)
1	1.315 (33.4)	0.957 (24.3)	0.179 (4.55)	0.719 (4.64)	2.19 (3.25)	2.36 (3.52)	2.42 (3.61)
1¼	1.660 (42.2)	1.278 (32.5)	0.191 (4.85)	1.283 (8.28)	3.01 (4.47)	3.26 (4.85)	3.34 (4.97)
1½	1.900 (48.3)	1.500 (38.1)	0.200 (5.08)	1.767 (11.4)	3.65 (5.42)	3.95 (5.88)	4.05 (6.03)
2	2.375 (60.3)	1.939 (49.3)	0.218 (5.54)	2.953 (19.1)	5.05 (7.50)	5.46 (8.12)	5.60 (8.34)
2½	2.875 (73.0)	2.323 (59.0)	0.276 (7.01)	4.238 (27.3)	7.71 (11.4)	8.33 (12.4)	8.55 (12.7)
3	3.500 (88.9)	2.900 (73.7)	0.300 (7.62)	6.605 (42.6)	10.3 (15.3)	11.1 (16.6)	11.4 (17.0)
3½	4.000 (102)	3.364 (85.5)	0.318 (8.08)	8.888 (57.3)	12.6 (18.7)	13.6 (20.2)	13.9 (20.8)
4	4.500 (114)	3.826 (97.2)	0.337 (8.56)	11.497 (74.)	15.1 (22.4)	16.3 (24.2)	16.7 (24.9)
5	5.562 (141)	4.812 (122)	0.375 (9.53)	18.186 (117)	20.9 (31.1)	22.6 (33.6)	23.2 (34.5)
6	6.625 (168)	5.761 (146)	0.432 (10.9)	26.067 (168)	28.7 (42.6)	31.1 (46.2)	31.9 (47.4)
8	8.625 (219)	7.625 (194)	0.500 (12.7)	45.664 (295)	43.6 (64.8)	47.2 (70.2)	48.4 (72.0)
10	10.750 (273)	9.750 (248)	0.500 (12.7)	74.7 (482)	55.1 (81.9)	59.5 (88.5)	61.1 (90.9)

TABLE 4 Dimensional Limits for Standard Pipe Sizes

Copper Alloy UNS No. C61300 and C61400

Nominal or Standard Pipe Size	Outside Diameter, in. (mm)	Min	Max	Regular			Extra Strong		
				Wall Thickness, in. (mm)	Min	Max	Wall Thickness, in. (mm)	Min	Max
⅛	0.405 (10.3)	0.374 (9.50)	0.421 (10.7)	0.068 (1.73)	0.061 (1.55)	0.075 (1.91)	0.095 (2.41)	0.086 (2.18)	0.105 (2.67)
¼	0.540 (13.7)	0.509 (12.9)	0.556 (14.1)	0.088 (2.24)	0.079 (2.01)	0.097 (2.46)	0.119 (3.02)	0.107 (2.72)	0.131 (3.33)
⅜	0.675 (17.1)	0.644 (16.4)	0.691 (17.6)	0.091 (2.31)	0.082 (2.08)	0.100 (2.54)	0.126 (3.20)	0.113 (2.87)	0.139 (3.53)
½	0.840 (21.3)	0.809 (20.5)	0.856 (21.7)	0.109 (2.77)	0.098 (2.49)	0.120 (3.05)	0.147 (3.73)	0.132 (3.35)	0.162 (4.11)
¾	1.050 (26.7)	1.019 (25.9)	1.066 (27.1)	0.113 (2.87)	0.102 (2.59)	0.124 (3.15)	0.154 (3.91)	0.139 (3.53)	0.169 (4.29)
1	1.315 (33.4)	1.284 (32.6)	1.331 (33.8)	0.133 (3.38)	0.120 (3.05)	0.146 (3.71)	0.179 (4.55)	0.161 (4.09)	0.197 (5.00)
1¼	1.660 (42.2)	1.629 (41.4)	1.676 (42.6)	0.140 (3.56)	0.126 (3.20)	0.154 (3.91)	0.191 (4.85)	0.172 (4.37)	0.210 (5.33)
1½	1.900 (48.3)	1.869 (47.5)	1.916 (48.7)	0.145 (3.68)	0.131 (3.33)	0.160 (4.06)	0.200 (5.08)	0.180 (4.57)	0.220 (5.59)
2	2.375 (60.3)	2.351 (59.7)	2.399 (60.9)	0.154 (3.91)	0.139 (3.53)	0.169 (4.29)	0.218 (5.54)	0.196 (4.98)	0.240 (6.10)
2½	2.875 (73.0)	2.846 (72.3)	2.904 (73.8)	0.203 (5.16)	0.183 (4.65)	0.223 (5.66)	0.276 (7.01)	0.248 (6.30)	0.304 (7.72)
3	3.500 (88.9)	3.465 (88.0)	3.535 (89.8)	0.216 (5.49)	0.194 (4.93)	0.238 (6.05)	0.300 (7.62)	0.270 (6.86)	0.330 (8.38)
3½	4.000 (102)	3.960 (101)	4.040 (103)	0.226 (5.74)	0.203 (5.16)	0.249 (6.32)	0.318 (8.08)	0.286 (7.26)	0.350 (8.89)
4	4.500 (114)	4.455 (113)	4.545 (115)	0.237 (6.02)	0.213 (5.41)	0.261 (6.63)	0.337 (8.56)	0.303 (7.70)	0.371 (9.42)
5	5.562 (141)	5.506 (140)	5.618 (143)	0.258 (6.55)	0.232 (5.89)	0.284 (7.21)	0.375 (9.53)	0.338 (8.59)	0.413 (10.5)
6	6.625 (168)	6.559 (167)	6.691 (170)	0.280 (7.11)	0.252 (6.40)	0.308 (7.82)	0.432 (11.0)	0.389 (9.88)	0.475 (12.1)
8	8.625 (219)	8.539 (217)	8.711 (221)	0.322 (8.18)	0.290 (7.37)	0.354 (8.99)	0.500 (12.7)	0.450 (11.4)	0.550 (14.0)
10	10.750 (273)	10.643 (270)	10.858 (276)	0.365 (9.27)	0.329 (8.36)	0.402 (10.2)	0.500 (12.7)	0.450 (11.4)	0.550 (14.0)
12	12.750 (324)	12.623 (321)	12.878 (327)	0.375 (9.53)	0.338 (8.59)	0.413 (10.5)	...	...	...

TABLE 5 Dimensional Limits for Standard Pipe Sizes

Copper Alloy UNS No. C65100 and C65500

Nominal or Standard Pipe Size	Outside Diameter, in. (mm)	Min	Max	Regular			Extra Strong		
				Wall Thickness, in. (mm)	Min	Max	Wall Thickness, in. (mm)	Min	Max
⅛	0.405 (10.3)	0.374 (9.50)	0.421 (10.7)	0.068 (1.73)	0.065 (1.65)	0.083 (2.11)	0.095 (2.41)	0.090 (2.29)	0.123 (3.12)
¼	0.540 (13.7)	0.509 (12.9)	0.556 (14.1)	0.088 (2.24)	0.084 (2.13)	0.102 (2.59)	0.119 (3.02)	0.107 (2.72)	0.144 (3.66)
⅜	0.675 (17.1)	0.644 (16.4)	0.691 (17.6)	0.091 (2.31)	0.086 (2.18)	0.103 (2.62)	0.126 (3.20)	0.120 (3.05)	0.146 (3.71)
½	0.840 (21.3)	0.809 (20.5)	0.856 (21.7)	0.109 (2.77)	0.104 (2.64)	0.122 (3.10)	0.147 (3.73)	0.140 (3.56)	0.166 (4.22)
¾	1.050 (26.7)	1.019 (25.9)	1.066 (27.1)	0.113 (2.87)	0.107 (2.72)	0.124 (3.15)	0.154 (3.91)	0.146 (3.71)	0.171 (4.34)
1	1.315 (33.4)	1.284 (32.6)	1.331 (33.8)	0.133 (3.38)	0.126 (3.20)	0.145 (3.68)	0.179 (4.55)	0.170 (4.32)	0.196 (4.98)
1¼	1.660 (42.2)	1.629 (41.4)	1.676 (42.6)	0.140 (3.56)	0.133 (3.38)	0.151 (3.84)	0.191 (4.85)	0.181 (4.60)	0.207 (5.26)
1½	1.900 (48.3)	1.889 (47.5)	1.916 (48.7)	0.145 (3.68)	0.138 (3.51)	0.156 (3.96)	0.200 (5.08)	0.190 (4.83)	0.216 (5.49)
2	2.375 (60.3)	2.351 (59.7)	2.399 (60.9)	0.154 (3.91)	0.146 (3.71)	0.164 (4.17)	0.218 (5.54)	0.207 (5.26)	0.233 (5.92)
2½	2.875 (73.0)	2.846 (72.3)	2.904 (73.8)	0.203 (5.16)	0.193 (4.90)	0.217 (5.51)	0.276 (7.01)	0.262 (6.65)	0.295 (7.49)
3	3.500 (88.9)	3.465 (88.0)	3.535 (89.8)	0.216 (5.49)	0.205 (5.21)	0.230 (5.84)	0.300 (7.62)	0.285 (7.24)	0.321 (8.15)
3½	4.000 (102)	3.960 (101)	4.040 (103)	0.226 (5.74)	0.215 (5.46)	0.240 (6.10)	0.318 (8.08)	0.302 (7.67)	0.340 (8.64)
4	4.500 (114)	4.455 (113)	4.545 (115)	0.237 (6.02)	0.225 (5.72)	0.252 (6.40)	0.337 (8.56)	0.320 (8.13)	0.360 (9.14)
5	5.562 (141)	5.506 (140)	5.618 (143)	0.258 (6.55)	0.245 (6.22)	0.275 (6.99)	0.375 (9.53)	0.356 (9.04)	0.400 (10.2)
6	6.625 (168)	6.559 (167)	6.691 (170)	0.280 (7.11)	0.266 (6.76)	0.298 (7.57)	0.432 (11.0)	0.410 (10.4)	0.461 (11.7)
8	8.625 (219)	8.539 (217)	8.711 (221)	0.322 (8.18)	0.299 (7.59)	0.349 (8.86)	0.500 (12.7)	0.465 (11.8)	0.544 (13.8)
10	10.750 (273)	10.643 (270)	10.858 (276)	0.365 (9.27)	0.336 (8.53)	0.400 (10.2)	0.500 (12.7)	0.460 (11.7)	0.548 (13.9)
12	12.750 (324)	12.623 (321)	12.878 (327)	0.375 (9.53)	0.345 (8.76)	0.410 (10.4)	...	...	...

TABLE 6 Wall Thickness Tolerances for Copper Alloy UNS No. C61300 and C61400 Tube (Not Applicable to Pipe)

NOTE—*Maximum Deviation at Any Point*—The following tolerances are plus and minus; if tolerances all plus or all minus are desired, double the values given.

Wall Thickness, in. (mm)	Outside Diameter, in. (mm)		
	Over ⅝ to 1 (15.9 to 25.4) incl	Over 1 to 2 (25.4 to 50.8) incl	Over 2 to 4 (50.8 to 102) incl
Over 0.024 (0.610) to 0.034 (0.864), incl	0.003 (0.076)	0.004 (0.10)	0.004 (0.10)
Over 0.034 (0.864) to 0.057 (1.45), incl	0.0045 (0.11)	0.005 (0.13)	0.006 (0.15)
Over 0.057 (1.45) to 0.082 (2.08), incl	0.005 (0.13)	0.006 (0.15)	0.008 (0.20)
Over 0.082 (2.08) to 0.119 (3.02), incl	0.007 (0.18)	0.008 (0.20)	0.009 (0.23)
Over 0.119 (3.02) to 0.164 (4.17), incl	0.009 (0.23)	0.010 (0.25)	0.012 (0.30)

TABLE 7 Wall Thickness Tolerances for Copper Alloy UNS No. C65500 Tube (Not Applicable to Pipe)

NOTE—*Maximum Deviation at Any Point*—The following tolerances are plus and minus: if tolerances all plus or all minus are desired, double the values given.

Wall Thickness, in. (mm)	Outside Diameter,[A] in. (mm)						
	1/32 to ⅛ (0.792 to 3.18), incl	Over ⅛ to ⅝ (3.18 to 15.9), incl	Over ⅝ to 1 (15.9 to 25.4), incl	Over 1 to 2 (25.4 to 50.8), incl	Over 2 to 4 (50.8 to 102), incl	Over 4 to 7 (102 to 173), incl	Over 7 to 10 (173 to 251), incl
Up to 0.017 (0.432), incl	0.0025 (0.064)	0.0015 (0.038)	0.002 (0.051)	0.0025 (0.064)	...	...	...
Over 0.017 (0.432) to 0.024 (0.610), incl	0.004 (0.10)	0.0025 (0.064)	0.0025 (0.064)	0.003 (0.076)	...	...	...
Over 0.024 (0.610) to 0.034 (0.864), incl	0.004 (0.10)	0.003 (0.076)	0.003 (0.076)	0.004 (0.10)	0.005 (0.13)	...	...
Over 0.034 (0.864) to 0.057 (1.45), incl	0.004 (0.10)	0.001 (0.10)	0.0045 (0.11)	0.0045 (0.11)	0.0065 (0.17)	0.009 (0.23)	...
Over 0.057 (1.45) to 0.082 (2.08), incl	...	0.0045 (0.11)	0.005 (0.13)	0.005 (0.13)	0.0075 (0.19)	0.010 (0.25)	0.013 (0.33)
Over 0.082 (2.08) to 0.119 (3.02), incl	...	0.005 (0.13)	0.0065 (0.17)	0.0065 (0.17)	0.009 (0.23)	0.011 (0.28)	0.014 (0.36)
Over 0.119 (3.02) to 0.164 (4.17), incl	...	0.007 (0.18)	0.007 (0.18)	0.0075 (0.19)	0.010 (0.25)	0.013 (0.33)	0.015 (0.38)
Over 0.164 (4.17) to 0.219 (5.56), incl	...	...	0.009 (0.23)	0.010 (0.25)	0.012 (0.30)	0.015 (0.38)	0.018 (0.46)
Over 0.219 (5.56) to 0.283 (7.19), incl	...	...	0.012 (0.30)	0.013 (0.33)	0.015 (0.38)	0.018 (0.46)	0.020 (0.51)
Over 0.283 (7.19) to 0.379 (9.62), incl	...	...	0.014 (0.36)	6[B]	6[B]	8[B]	8[B]
Over 0.379 (9.62)	...	...	...	6[B]	6[B]	8[B]	8[B]

[A] When tube is ordered by outside and inside diameters, the maximum plus and minus deviation of the wall thickness from the nominal at any point shall not exceed the values given in this table by more than 50 %.

[B] Percent of the specified wall thickness expressed to the nearest 0.001 in. (0.025 mm).

TABLE 8 Wall Thickness Tolerances for Copper Alloy UNS No. C65100 Tube (Not Applicable to Pipe)

NOTE—*Maximum Deviation at Any Point*—The following tolerances are plus and minus: if tolerances all plus or all minus are desired, double the values given.

Wall Thickness, in. (mm)	Outside Diameter, in.[A] (mm)						
	1/32 (0.792) to 1 1/8 (3.18), incl	Over 1/8 (3.18) to 5/8 (15.9), incl	Over 5/8 (15.9) to 1 (25.4), incl	Over 1 (25.4) to 2 (50.8), incl	Over 2 (50.8) to 4 (102), incl	Over 4 (102) to 7 (213), incl	Over 7 (213) to 10 (254), incl
Up to 0.017 (0.432), incl	0.002 (0.051)	0.001 (0.025)	0.0015 (0.038)	0.002 (0.051)	...	...	...
Over 0.017 (0.432) to 0.024 (0.610), incl	0.003 (0.076)	0.002 (0.051)	0.002 (0.051)	0.0025 (0.064)	...	...	...
Over 0.024 (0.610) to 0.034 (0.864), incl	0.003 (0.076)	0.0025 (0.064)	0.0025 (0.064)	0.003 (0.076)	0.004 (0.10)	...	...
Over 0.034 (0.864) to 0.057 (1.45), incl	0.003 (0.076)	0.003 (0.076)	0.0035 (0.089)	0.0035 (0.089)	0.005 (0.13)	0.007 (0.18)	...
Over 0.057 (1.45) to 0.082 (2.08), incl	...	0.0035 (0.089)	0.004 (0.10)	0.004 (0.10)	0.006 (0.15)	0.008 (0.20)	0.010 (0.26)
Over 0.082 (2.08) to 0.119 (3.02), incl	...	0.004 (0.10)	0.005 (0.13)	0.005 (0.13)	0.007 (0.18)	0.009 (0.23)	0.011 (0.28)
Over 0.119 (3.02) to 0.164 (4.17), incl	...	0.005 (0.13)	0.006 (0.15)	0.006 (0.15)	0.008 (0.20)	0.010 (0.25)	0.012 (0.30)
Over 0.164 (4.17) to 0.219 (5.56), incl	...	0.007 (0.18)	0.0075 (0.19)	0.008 (0.20)	0.010 (0.25)	0.012 (0.30)	0.014 (0.36)
Over 0.219 (5.56) to 0.283 (7.19), incl	...	...	0.009 (0.23)	0.010 (0.25)	0.012 (0.30)	0.014 (0.36)	0.016 (0.44)
Over 0.283 (7.19) to 0.379 (9.62), incl	...	...	0.012 (0.30)	5[B]	5[B]	6[B]	6[B]
Over 0.379 (9.62), incl	...	...	...	5[B]	5[B]	6[B]	6[B]

[A] When round tube is ordered by outside and inside diameters, the maximum plus and minus deviation of the wall thickness from the nominal at any point shall not exceed the values given in the table by more than 50 %.

[B] Percent of the specified wall thickness expressed to the nearest 0.001 in. (0.025 mm).

TABLE 9 Average Diameter Tolerances for Tube (Not Applicable to Pipe)

Specified Diameter, in. (mm)	Tolerance, ± in. (mm)[A]		
	Copper Alloy UNS No. C61300 and C61400	C65100	C65500
Up to 1/8 (3.18), incl	...	0.002 (0.051)[B]	0.003 (0.076)[B]
Up to 1/8 (3.18), incl	...	0.002 (0.051)[C]	0.0025 (0.064)[C]
Over 1/8 (3.18) to 5/8 (15.9), incl	0.004 (0.10)	0.002 (0.051)	0.0025 (0.064)
Over 5/8 (15.9) to 1 (25.4), incl	0.005 (0.13)	0.0025 (0.064)	0.003 (0.076)
Over 1 (25.4) to 2 (50.8), incl	0.006 (0.15)	0.003 (0.076)	0.004 (0.10)
Over 2 (50.8) to 3 (76.2), incl	0.007 (0.18)	0.004 (0.10)	0.005 (0.13)
Over 3 (76.2) to 4 (102), incl	...	0.005 (0.13)	0.006 (0.15)
Over 4 (102) to 5 (127), incl	...	0.006 (0.15)	0.008 (0.20)
Over 5 (127) to 6 (152), incl	...	0.007 (0.18)	0.009 (0.23)
Over 6 (152) to 8 (203), incl	...	0.008 (0.20)	0.010 (0.25)
Over 8 (203) to 10 (254), incl	...	0.010 (0.25)	0.013 (0.33)

[A] Tolerance applies to inside or outside diameters, except as noted.

[B] On inside diameter.

[C] On outside diameter.

TABLE 10 Length Tolerances

NOTE—*Tolerances are all plus*—If all minus tolerances are desired, use the same value. If tolerances plus and minus are desired, halve the values given.

Length	Tolerances, in. (mm), Applicable Only to Full Length Pieces		
	Outside Diameters up to 1 in. (25.4 mm), incl	Outside Diameters over 1 in. (25.4 mm) to 4 in. (102 mm), incl	Outside Diameters over 4 in. (102 mm)
Specific lengths:			
Up to 6 in. (152 mm), incl	1/32 (0.79)	1/16 (1.6)	...
Over 6 in. (152 mm) to 2 ft (610 mm), incl	1/16 (1.6)	3/32 (2.4)	1/8 (3.2)
Over 2 ft (610 mm) to 6 ft (1.83 m), incl	3/32 (2.4)	1/8 (3.2)	1/4 (6.4)
Over 6 ft (1.83 m) to 14 ft (4.27 m), incl	1/4 (6.4)	1/4 (6.4)	1/4 (6.4)
Over 14 ft (4.27 m)	1/2 (13)	1/2 (13)	1/2 (13)
Specific lengths with ends	1 (25)	1 (25)	1 (25)
Stock lengths with or without ends	1[A] (25)	1[A] (25)	1[A] (25)

[A] As stock lengths are cut and placed in stock in advance of orders, departure from this tolerance is not practicable.

TABLE 11 Schedule of Tube Lengths (Specific and Stock) with Ends

Outside Dimensions, in. (mm)	Specific Length, ft (m)	Shortest Permissible Length,[A] % of Specific Length	Maximum Permissible Weight of Ends, % of Lot Weight
Up to 1 (25.4), incl	6 (1.83) to 20 (6.10), incl	70	20
Over 1 (25.4) to 2 (50.8), incl	6 (1.83) to 20 (6.10), incl	60	25
Over 2 (50.8) to 3 (76.2), incl	6 (1.83) to 20 (6.10), incl	55	30
Over 3 (76.2) to 4 (102), incl	6 (1.83) to 20 (6.10), incl	50	40

[A] Expressed to nearest 1/3 ft.

Nominal or Standard Pipe Size, in.	Lot Weight, lb (kg)
Up to 4, incl	10 000 (4550) or fraction thereof
Over 4	40 000 (18 100) or fraction thereof

11. Workmanship, Finish, and Appearance

11.1 The material shall be free from defects of a nature that interfere with normal commercial applications and shall be free of heavy oxides and dirt.

11.2 Copper Alloy UNS Nos. 65100 and 65500 may be supplied in the following finishes:

11.2.1 *Specially Cleaned*—Commercially free of all oxides, this material has the golden color of the alloy. It is intended for brazing and welding operations.

11.2.2 Plain pickled, or with dull iridescent film on both the inside and outside surfaces. Plain pickled material normally has a brick red color with cuprous and silicon oxides still adherent.

11.3 Copper Alloy UNS Nos. C61300 and C61400 shall be supplied with the normal as-extruded or annealed tarnish unless otherwise specified on the purchase order.

12. Sampling

12.1 *Sampling*—The lot size, portion size, and selection of sample pieces shall be as follows:

12.1.1 *Lot Size*—For tube, the lot size shall be 10 000 lb (4550 kg) or fraction thereof. For pipe, the lot size shall be as follows:

12.1.2 *Portion Size*—Sample pieces shall be taken for test purposes from each lot according to the following schedule:

Number of Pieces in Lot	Number of Sample Pieces to be Taken
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2 % of total number of pieces in the lot

13. Number of Test and Retests

13.1 *Chemical Analysis*—Samples for chemical analysis shall be taken in accordance with Practice E 55. Drillings, millings, etc., shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 12.1.2 and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

13.1.1 Instead of sampling in accordance with Practice E 55, the manufacturer shall have the option of determining conformance to chemical composition as follows: Conformance shall be determined by the manufacturer by analyzing samples taken at the time the castings are poured or samples taken from the semifinished product. If the manufacturer determines the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product. The number of samples taken for determination of chemical composition shall be as follows:

13.1.1.1 When samples are taken at the time the 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 samples are taken from the semifinished product, a sample shall be taken to represent each 10 000 lb (4550 kg) or fraction thereof for all tube and for pipe sizes up to 4 in., inclusive and 40 000 lb (18 100 kg) for pipe sizes over 4 in., except that not more than one sample shall be required per piece.

13.1.1.3 Due to the discontinuous nature of the processing of castings into wrought products, it is not practical to identify specific casting analysis with a specific quantity of finished material.

13.1.1.4 In the event that heat identification or traceability is required, the purchaser shall specify the details desired.

13.2 *Tension Tests*—For the tension tests, a specimen shall be taken from each of the pieces selected in accordance with 12.1. The required tension test shall be made on each of the specimens so selected.

13.3 *Pressure Tests*—For the purpose of pressure testing only, a number of lengths of pipe or tube to be tested as described in 9.1.2 shall be randomly selected from the lot as follows:

Number of Pipe or Tubes	
Lot Size	Sample Size
1–8	5
9–50	7
51–150	20
151–280	32
281–500	50
501–1200	80
1201–3200	125

13.4 *Retests:*

13.4.1 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

13.4.2 If the percentage elongation of any tension test specimen is less than that specified and any part of the fracture is outside the middle two thirds of the gage length or in a punched or scribed mark within the reduced section, a retest shall be allowed.

13.4.3 If the results of any test made to determine the physical properties fail to meet the specified limits, this test shall be repeated on each of two additional specimens taken from different pieces and the results of both of these tests shall comply with the specified requirements.

13.4.4 If the chemical analysis fails to conform to the specified limits, analysis shall be made on a new composite sample prepared from additional pieces selected in accordance with 12.1. The results of this retest shall comply with the specified requirements.

13.4.5 If any test specimen representing a lot fails to conform to the requirements of 9.1.2, two additional specimens, at the option of the manufacturer, may be taken as before, and submitted for check analysis or subjected to any tests in which the original specimen failed, but each of these specimens shall conform to the requirements specified.

14. Test Methods

14.1 The properties enumerated in this specification shall, in case of disagreement, be determined in accordance with the following applicable methods of the American Society for Testing and Materials:

Test	ASTM Designation
Chemical analysis	E 54
Tension test	E 8

(See also 14.2, 14.3, and 14.4)

14.2 Tension test specimens shall be of the full section of the tube and shall conform to the requirements of Specimens for Pipe and Tube section, of Test Methods E 8, unless the limitations of the testing machine preclude the use of such a specimen. Test specimens conforming to Type No. 1 of Fig. 13, Tension Test Specimens for Large-Diameter Tubular Products, of Test Methods E 8 may be used when a full-section specimen cannot be tested.

14.3 Whenever tension test results are obtained from both full-size and from machined test specimens and they differ, the results obtained from full-size test specimens shall be used to determine conformance to the specification requirements.

14.4 Tension test results on material covered by this specification are not seriously affected by variations in speed of testing. A considerable range of testing speed is permissible; however, the rate of stressing to the yield strength should not exceed 100 ksi (690 MPa)/min. Above the yield strength the movement per minute of the testing machine head under load should not exceed 0.5 in./in. (0.5 mm/mm) of gage length (or distance between grips for full-section specimens).

15. Significance of Numerical Limits

15.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value

shall be rounded as indicated in accordance with the rounding method of Practice E 29.

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	nearest unit in the last right-hand place of figures of the specified limit
Tensile strength, Yield strength	nearest ksi (nearest 5 MPa)
Elongation	nearest 1 %

16. Inspection

16.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material is being furnished in accordance with the specified requirements.

17. Rejection and Rehearing

17.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer or supplier may make claim for a rehearing.

18. Packaging and Package Marking

18.1 The material shall be separated by size, composition, and temper, and prepared for shipment in such a manner as to ensure acceptance by common carrier for transportation and to afford protection from the normal hazards of transportation.

18.2 Each shipping unit shall be legibly marked with the purchase order number, metal or alloy designation, temper, size, shape, gross and net weight, and name of supplier. The specification number shall be shown, when specified.

19. Certification

19.1 When specified in the purchase order or contract, a manufacturer's certificate of compliance shall be furnished to the purchaser stating that each lot has been sampled, tested, and inspected in accordance with this specification and the requirements have been met. When material is specified to meet the requirements of *ASME Boiler and Pressure Vessel Code*, the certification requirements are mandatory.

20. Test Report

20.1 When specified in the purchase order or contract, the manufacturer or supplier shall furnish to the purchaser a manufacturer's test report showing the results of the required tests.

APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 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.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B42: Standard Specification for Seamless Copper Pipe, Standard Sizes

CFR Section(s): 46 CFR 56.60-1(b)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 42 – 96

Standard Specification for Seamless Copper Pipe, Standard Sizes[1]

This standard is issued under the fixed designation B 42; 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 specification has been approved for use by agencies of the Department of Defense. Replaces WW-P-377. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification[2] covers seamless copper pipe in all nominal or standard pipe sizes, both regular and extra-strong, suitable for use in plumbing, boiler feed lines, and for similar purposes.[3]

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes 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 referenced herein:

2.1.1 *ASTM Standards:*

B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing[4]

B 170 Specification for Oxygen-Free Electrolytic Copper Refinery Shapes[4]

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[4]

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

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[6]

E 53 Test Methods for Chemical Analysis of Copper[7]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[7]

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)[7]

E 243 Practice for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes[8]

E 478 Test Methods for Chemical Analysis of Copper Alloys[7]

E 527 Practice for Numbering Metals and Alloys (UNS)[9]

3. Terminology

3.1 *Definitions:*

3.1.1 *lengths*—straight pieces of the product.

3.1.1.1 *standard*—uniform lengths recommended in a Simplified Practice Recommendation or established as a Commercial Standard.

3.1.2 *tube, seamless*—a tube produced with a continuous periphery in all stages of the operations.

3.1.2.1 *pipe*—a seamless tube conforming to the particular dimensions commercially known as Nominal or Standard Pipe Sizes.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *capable of*—as used in this specification, the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Type of copper, if required,

4.1.2 Temper (see 6.1),

4.1.3 Pipe size, regular or extra-strong, (see 10.2),

4.1.4 Length (see 10.3),

4.1.5 Total length of each size,

4.1.6 If material is required to meet *ASME Boiler and Pressure Vessel Code*,

4.1.7 Certification, if required (see 19.1),

4.1.8 Mill test report, if required (see 20.1),

4.1.9 Hydrostatic test, if required, and

4.1.10 Pneumatic test, if required.

4.2 In addition, when material is purchased for agencies of the U.S. Government, it shall conform to the Supplementary Requirements as defined herein when specified in the contract or purchase order.

5. Chemical Composition

5.1 The material shall conform to the following chemical requirements:

Copper (incl silver), min, %	99.9
Phosphorus, max, %	0.04

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.04 on Pipe and Tube.

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[2] For *ASME Boiler and Pressure Vessel Code* applications see related Specification SB-42 in Section II of that Code.

[3] 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.

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

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

[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 03.03.

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

TABLE 1 Chemical Requirements

Copper UNS No.	Copper (incl Silver), min, %	Phosphorus, %
C10200[A]	99.95	...
C10300	99.95[B]	0.001 to 0.005
C10800	99.95[B]	0.005 to 0.012
C12000	99.90	0.004 to 0.012
C12200	99.9	0.015 to 0.040

[A] Oxygen in C10200 shall be 10 ppm max.
[B] Copper + silver + phosphorus.

5.2 The pipe shall be produced from one of the following coppers, and unless otherwise specified, anyone of them is permitted to be furnished:

Copper UNS No.	Previously Used Designation	Type of Copper
C10200	OF	Oxygen-free without residual deoxidants
C10300		Oxygen-free, extra-low phosphorus
C10800		Oxygen-free, low phosphorus
C12000	DLP	Phosphorized, low residual phosphorus
C12200	DHP	Phosphorized, high residual phosphorus

5.3 When the copper is specified, the material shall conform to the chemical requirements specified in Table 1.

5.4 These specification limits do not preclude the possible presence of other elements. When required, limits for unnamed elements are to be established by agreement between manufacturer or supplier and purchaser.

5.4.1 The major element that is not analyzed shall be determined by difference between the sum of those elements analyzed and 100 %. By agreement between manufacturer and purchaser, it is permitted to establish limits and required analysis for elements not specified.

6. Temper

6.1 All pipe shall normally be furnished in the O61 (annealed), H55 (light drawn), or H80 (hard drawn) temper, as prescribed in Practice B 601, and shall have the properties shown in Table 2.

6.2 When pipe is required for bending, it shall be so specified in the purchase order, and the pipe shall be furnished in the temper agreed upon between the manufacturer or supplier and the purchaser.

7. Expansion Test

7.1 Pipe ordered in the annealed (O) condition, selected for test, shall withstand an expansion of 25% of the outside diameter when expanded in accordance with Test Method B 153. The expanded pipe shall show no cracking or rupture visible to the unaided eye. Pipe ordered in the drawn (H) condition is not subject to this test.

NOTE 1—The term "unaided eye," as used herein, permits the use of corrective spectacles necessary to obtain normal vision.

7.2 As an alternative to the expansion test for pipe over 4 in. (102 mm) in diameter in the annealed condition, a section 4 in. in length shall be cut from the end of one of the lengths for a flattening test. This 4-in. specimen shall be flattened so that a gage set at three times the wall thickness will pass over the pipe freely throughout the flattened part. The pipe so tested shall develop no cracks or flaws visible to the unaided eye (Note 1) as a result of this test. In making the flattening test the elements shall be slowly flattened by one stroke of the press.

TABLE 2 Tensile Requirements

Temper Designation		Pipe Size Nominal or Standard, in.	Tensile Strength, min, ksi[B] (MPa)[C]	Yield Strength,[A] min, ksi[B] (MPa)[C]
Standard	Former			
O61	annealed	all	30 (294)	9 (88)[D]
H80	hard drawn	⅛–2, incl	45 (310)	40 (280)
H55	light drawn	2–12, incl	36 (250)	30 (210)

[A] At 0.5 % extension under load.
[B] ksi = 1000 psi.
[C] See Appendix X1.
[D] Light straightening operation is permitted.

8. Microscopical Examination

8.1 The pipe shall be made from copper that is free of cuprous oxide as determined by microscopical examination at a 75× magnification. When Copper UNS No. C12200 is supplied, microscopical examination for cuprous oxide is not required.

9. Nondestructive Testing

9.1 The material shall be tested in the final size but is permitted to be tested prior to the final anneal or heat treatment, when these thermal treatments are required, unless otherwise agreed upon by the manufacturer or supplier and purchaser.

9.2 *Eddy-Current Test*—Each piece of material from ⅛ in. up to and including 2½ in. nominal outside diameter, or within the capabilities of the eddy-current tester, shall be subjected to an eddy-current test. Testing shall follow the procedures of Practice E 243, except for determination of "end effect." The material shall be passed through an eddy-current testing unit adjusted to provide information on the suitability of the material for the intended application.

9.2.1 Notch-depth standards rounded to the nearest 0.001 in. (0.025 mm) shall be 10 % of the nominal wall thickness. The notch depth tolerance shall be ±0.0005 in. (0.013 mm). Alternatively, when a manufacturer uses speed insensitive equipment that allows the selection of a maximum imbalance signal, a maximum imbalance signal of 0.3 % is permitted to be used.

9.2.2 Material that does not actuate the signaling device of the eddy-current test shall be considered as conforming to the requirements of this test. Material with discontinuities indicated by the testing unit is permitted to be reexamined or retested, at the option of the manufacturer, to determine whether the discontinuity is cause for rejection. Signals that are found to have been caused by minor mechanical damage, soil or moisture shall not be cause for rejection of the material provided the dimensions of the material are still within prescribed limits and the material is suitable for its intended application.

9.3 *Hydrostatic Test*—When specified, the material shall stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 6000 psi (41 MPa), determined by the following equation for thin hollow cylinders under tension. The material need not be tested at a hydrostatic pressure of over 1000 psi (6.9 MPa) unless so specified.

$$P = 2St/(D - 0.8t)$$

TABLE 3 Standard Dimensions, Weights, and Tolerances

NOTE—All tolerances plus and minus except as otherwise indicated.

Nominal or Standard Pipe Size, in.	Outside Diameter, in. (mm)	Average Outside Diameter Tolerance,[A] in. (mm) All Minus	Wall Thickness, in. (mm)	Tolerance,[B] in. (mm)	Theoretical Weight, lb/ft (kg/m)
			Regular		
⅛	0.405 (10.3)	0.004 (0.10)	0.062 (1.57)	0.004 (0.10)	0.259 (0.385)
¼	0.540 (13.7)	0.004 (0.10)	0.082 (2.08)	0.005 (0.13)	0.457 (0.680)
⅜	0.675 (17.1)	0.005 (0.13)	0.090 (2.29)	0.005 (0.13)	0.641 (0.954)
½	0.840 (21.3)	0.005 (0.13)	0.107 (2.72)	0.006 (0.15)	0.955 (1.42)
¾	1.050 (26.7)	0.006 (0.15)	0.114 (2.90)	0.006 (0.15)	1.30 (1.93)
1	1.315 (33.4)	0.006 (0.15)	0.126 (3.20)	0.007 (0.18)	1.82 (2.71)
1¼	1.660 (42.2)	0.006 (0.15)	0.146 (3.71)	0.008 (0.20)	2.69 (4.00)
1½	1.900 (48.3)	0.006 (0.15)	0.150 (3.81)	0.008 (0.20)	3.20 (4.76)
2	2.375 (60.3)	0.008 (0.20)	0.156 (3.96)	0.009 (0.23)	4.22 (6.28)
2½	2.875 (73.0)	0.008 (0.20)	0.187 (4.75)	0.010 (0.25)	6.12 (9.11)
3	3.500 (88.9)	0.010 (0.25)	0.219 (5.56)	0.012 (0.30)	8.76 (13.0)
3½	4.000 (102)	0.010 (0.25)	0.250 (6.35)	0.013 (0.33)	11.4 (17.0)
4	4.500 (114)	0.012 (0.30)	0.250 (6.35)	0.014 (0.36)	12.9 (19.2)
5	5.562 (141)	0.014 (0.36)	0.250 (6.35)	0.014 (0.36)	16.2 (24.1)
6	6.625 (168)	0.016 (0.41)	0.250 (6.35)	0.014 (0.36)	19.4 (28.9)
8	8.625 (219)	0.020 (0.51)	0.312 (7.92)	0.022 (0.56)	31.6 (47.0)
10	10.750 (273)	0.022 (0.56)	0.365 (9.27)	0.030 (0.76)	46.2 (68.7)
12	12.750 (324)	0.024 (0.61)	0.375 (9.52)	0.030 (0.76)	56.5 (84.1)
			Extra Strong		
⅛	0.405 (10.3)	0.004 (0.10)	0.100 (2.54)	0.006 (0.15)	0.371 (0.552)
¼	0.540 (13.7)	0.004 (0.10)	0.123 (3.12)	0.007 (0.18)	0.625 (0.930)
⅜	0.675 (17.1)	0.005 (0.13)	0.127 (3.23)	0.007 (0.18)	0.847 (1.26)
½	0.840 (21.3)	0.005 (0.13)	0.149 (3.78)	0.008 (0.20)	1.25 (1.86)
¾	1.050 (26.7)	0.006 (0.15)	0.157 (3.99)	0.009 (0.23)	1.71 (2.54)
1	1.315 (33.4)	0.006 (0.15)	0.182 (4.62)	0.010 (0.25)	2.51 (3.73)
1¼	1.660 (42.2)	0.006 (0.15)	0.194 (4.93)	0.010 (0.25)	3.46 (5.15)
1½	1.900 (48.3)	0.006 (0.15)	0.203 (5.16)	0.011 (0.28)	4.19 (6.23)
2	2.375 (60.3)	0.008 (0.20)	0.221 (5.61)	0.012 (0.30)	5.80 (8.63)
2½	2.875 (73.0)	0.008 (0.20)	0.280 (7.11)	0.015 (0.38)	8.85 (13.2)
3	3.500 (88.9)	0.010 (0.25)	0.304 (7.72)	0.016 (0.41)	11.8 (17.6)
3½	4.000 (102)	0.010 (0.25)	0.321 (8.15)	0.017 (0.43)	14.4 (21.4)
4	4.500 (114)	0.012 (0.30)	0.341 (8.66)	0.018 (0.46)	17.3 (25.7)
5	5.562 (141)	0.014 (0.36)	0.375 (9.52)	0.019 (0.48)	23.7 (35.3)
6	6.625 (168)	0.016 (0.41)	0.437 (11.1)	0.027 (0.69)	32.9 (49.0)
8	8.625 (219)	0.020 (0.51)	0.500 (12.7)	0.035 (0.89)	49.5 (73.7)
10	10.750 (273)	0.022 (0.56)	0.500 (12.7)	0.040 (1.0)	62.4 (92.9)

[A] The average outside diameter of a tube is the average of the maximum and minimum outside diameters as determined at any one cross section of the pipe.
[B] Maximum deviation at any one point.

where:
P = hydrostatic pressure, psi (or MPa),
t = wall thickness of the material, in. (or mm),
D = outside diameter of the material in. (or mm), and
S = allowable stress of the material, psi (or MPa).

9.4 *Pneumatic Test*—When specified, the material shall be subjected to an internal air pressure of 60 psi (415 kPa) minimum for 5 s without showing evidence of leakage. The test method used shall permit easy visual detection of any leakage, such as by having the material under water or by the pressure-differential method. Any evidence of leakage shall be cause for rejection.

10. Dimensions and Permissible Variations

10.1 For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the limiting values for any dimensions shall be sufficient cause for rejection.

10.2 *Standard Dimensions, Wall Thickness, and Diameter Tolerances*—The standard dimensions, wall thickness, and diameter tolerances shall be in accordance with Table 3.

10.3 *Length and Length Tolerances*—The standard length of copper pipe is 12 ft (3.66 m) with a tolerance of ±½ in. (13 mm).

10.4 *Roundness:*

10.4.1 For drawn unannealed pipe in straight lengths, the roundness tolerances shall be as follows:

t/d (ratio of Wall Thickness to Outside Diameter)	Roundness Tolerances as Percent of Outside Diameter (Expressed to the Nearest 0.001 in. (0.025 mm))
0.01 to 0.03, incl	1.5
Over 0.03 to 0.05, incl	1.0
Over 0.05 to 0.10, incl	0.8
Over 0.10	0.7

10.4.2 Compliance with the roundness tolerance shall be determined by taking measurements on the outside diameter only, irrespective of the manner in which the pipe dimensions are specified.

10.4.3 The deviation from roundness is measured as the difference between major and minor diameters as determined at any one cross section of the tube.

10.5 *Squareness of Cut*—The departure from squareness of the end of any pipe shall not exceed the following:

Outside Diameter, in. (mm)	Tolerance
Up to ⅝ (15.9), incl	0.010 in. (0.25 mm)
Over ⅝ (15.9)	0.016 in./in. (0.016 mm/mm) of diameter

11. Workmanship, Finish, and Appearance

11.1 The material shall be free of defects of a nature that interfere with normal commercial applications. It shall be well cleaned and free of dirt.

12. Sampling

12.1 *Sampling*—The lot size, portion size, and selection of sample pieces shall be as follows:

12.1.1 *Lot Size*—The lot size shall be as follows:

Pipe Size, in.	Lot Weight, lb (kg)
Up to 1½, incl	5 000 (2270) or fraction thereof
Over 1½ to 4, incl	10 000 (4550) or fraction thereof
Over 4	40 000 (18 100) or fraction thereof

12.1.2 *Portion Size*—Sample pieces shall be taken for test purposes from each lot according to the following schedule:

Number of Pieces in Lot	Number of Sample Pieces to be Taken[A]
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2 % of total number of pieces in the lot, but not to exceed 10 sample pieces

[A] Each sample piece shall be taken from a separate tube.

13. Number of Tests and Retests

13.1 *Chemical Analysis*—Samples for chemical analysis shall be taken in accordance with Practice E 55. Drillings, millings, etc., shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 12.1.2 and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

13.1.1 Instead of sampling in accordance with Practice E 55, the manufacturer shall have the option of determining conformance to chemical composition as follows: Conformance shall be determined by the manufacturer by analyzing samples taken at the time the castings are poured or samples taken from the semi-finished product. If the manufacturer determines the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product. The number of samples taken for determination of chemical composition shall be as follows:

13.1.1.1 When samples are taken at the time the 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 samples are taken from the semi-finished product, a sample shall be taken to represent each 10 000 lb (4550 kg) or fraction thereof, except that not more than one sample shall be required per piece.

13.1.1.3 Due to the discontinuous nature of the processing of castings into wrought products, it is not practical to identify specific casting analysis with a specific quantity of finished material.

13.1.1.4 In the event that heat identification or traceability is required, the purchaser shall specify the details desired.

13.2 *Retests:*

13.2.1 If any test specimen shows defective machining or develops flaws, it shall be discarded and another specimen substituted.

13.2.2 If a bend test specimen fails, due to conditions of bending more severe than required by the specification, a retest shall be permitted on a new sample piece or on the remaining portion of the first sample piece.

13.2.3 If the results of the test on one of the specimens fail to meet the specified requirements, two additional specimens shall be taken from different sample pieces and tested. The results of the tests on both of these specimens shall meet the specified requirements. Failure of more than one specimen to meet the specified requirements for a particular property shall be cause for rejection of the entire lot.

13.2.4 If the chemical analysis fails to conform to the specified limits, analysis shall be made on a new composite sample prepared from additional pieces selected in accordance with 12.1. The results of this retest shall comply with the specified requirements.

14. Test Methods

14.1 The properties enumerated in this specification shall, in case of disagreement, be determined in accordance with the following applicable test methods:

Test	ASTM Designation[A]
Chemical analysis	B 170[B], E 53, E 62, E 478
Tension	E 8
Expansion (pin test)	B 153
Eddy current	E 243

[A] See 2.1.

[B] Reference to Specification B 170 is to the suggested chemical methods in the annex thereof. When Committee E-1 has tested and published methods for assaying the low level impurities in copper, the Specification B 170 annex will be eliminated.

14.2 Tension test specimens shall be of the full section of the pipe and shall conform to the requirements of the Specimens for Pipe and Tube section, of Test Methods E 8, unless the limitations of the testing machine preclude the use of such a specimen. Test specimens conforming to Type No. 1 of Fig. 13, Tension Test Specimens for Large-Diameter Tubular Products, of Test Methods E 8 is permitted to be used when a full section specimen cannot be tested.

14.3 Whenever tension test results are obtained from both full size and machined test specimens and they differ, the results obtained from full size test specimens shall be used to determine conformance to the specification requirements.

14.4 Tension test results on material covered by this specification are not seriously affected by variations in speed of testing. A considerable range of testing speed is permissible; however, it is recommended that the rate of stressing to the yield strength not exceed 100 ksi (700 MPa)/min. Above the yield strength it is recommended that the movement per minute of the testing machine head under load not exceed 0.5 in./in. (0.5 mm/mm) of gage length (or distance between grips for full-section specimens).

15. Significance of Numerical Limits

15.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated in accordance with the

rounding method of Practice E 29.

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	nearest unit in the last right-hand place of figures of the specified limit
Tensile strength Yield strength	nearest ksi (nearest 5 MPa)

16. Inspection

16.1 The manufacturer shall afford the inspector representing the purchaser all reasonable facilities, without charge, to satisfy him that the material is being furnished in accordance with the specified requirements.

17. Rejection and Rehearing

17.1 Material that fails to conform to the requirements of this specification shall be subject to rejection. Rejection is to be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer or supplier shall have the option to make claim for a rehearing.

18. Packaging and Package Marking

18.1 The material shall be separated by size, composition, and temper, and prepared for shipment in such a manner as to ensure acceptance by common carrier for transportation and to afford protection from the normal hazards of transportation.

18.2 Each shipping unit shall be legibly marked with the purchase order number, metal or alloy designation, temper, size, total length or piece count or both, and name of supplier. The specification number shall be shown, when specified.

19. Certification

19.1 When specified on the purchase order the manufacturer shall furnish to the purchaser a certificate stating that each lot has been sampled, tested, and inspected in accordance with this specification and has met the requirements. When material is specified to meet the requirements of *ASME Boiler and Pressure Vessel Code*, the certification requirements are mandatory.

20. Mill Test Report

20.1 When specified on the purchase order, the manufacturer shall furnish to the purchaser a test report showing results of tests required by the specification.

21. Keywords

21.1 copper pipe; extra strong; regular; standard sizes

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U. S. Government.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

S1.1.1 *Federal Standards:*[10]

Fed. Std. No. 102 Preservation, Packaging and Packing Levels

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 185 Identification Marking of Copper and Copper-Base Alloy Mill Products

S1.1.2 *Military Standard:*[10]

MIL-STD-129 Marking for Shipment and Storage

S1.1.3 *Military Specification:*[10]

MIL-C-3993 Packaging of Copper and Copper-Base Alloy Mill Products

S2. Quality Assurance

S2.1 *Responsibility for Inspection:*

S2.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer shall use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

S3. Identification Marking

S3.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 185 except that the ASTM specification number and the alloy number shall be used.

S4. Preparation for Delivery

S4.1 *Preservation, Packaging, Packing:*

S4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade, or class and shall be preserved and packaged, Level A or C, and packed, Level A, B, or C, as specified in the contract or purchase order, in accordance with the requirements of MIL-C-3993.

S4.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

[10] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, ATTN: NPODS.

APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 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.