



Designation: B944 – 22

Standard Specification for Copper-Beryllium Welded Heat Exchanger and Condenser Tube (UNS No. C17510)¹

This standard is issued under the fixed designation B944; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification establishes the requirements for copper-beryllium alloy UNS No. C17510 welded tube in straight lengths.

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

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

1.3.1 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

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

2. Referenced Documents

2.1 *ASTM Standards:*²

[B153 Test Method for Expansion \(Pin Test\) of Copper and Copper-Alloy Pipe and Tubing](#)

[B194 Specification for Copper-Beryllium Alloy Plate, Sheet, Strip, and Rolled Bar](#)

[B601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast](#)

[B846 Terminology for Copper and Copper Alloys](#)

[B968/B968M Test Method for Flattening of Copper and Copper-Alloy Pipe and Tube](#)

[E8/E8M Test Methods for Tension Testing of Metallic Materials](#)

[E18 Test Methods for Rockwell Hardness of Metallic Materials](#)

[E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications](#)

[E243 Practice for Electromagnetic \(Eddy Current\) Examination of Copper and Copper-Alloy Tubes](#)

[E255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition](#)

[E1004 Test Method for Determining Electrical Conductivity Using the Electromagnetic \(Eddy Current\) Method](#)

3. Terminology

3.1 For definitions of terms related to copper and copper alloys, refer to Terminology [B846](#).

4. Ordering Information

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

4.1.1 ASTM designation and year of issue,

4.1.2 Copper Alloy UNS No. designation,

4.1.3 Temper (Section 7),

4.1.4 Dimensions, diameter, and wall thickness (Section 12). For tube or pipe, specify either OD/wall, ID/wall, or OD/ID,

4.1.5 Minimum wall thickness or average (nominal) wall thickness,

4.1.6 Tube length, specific or random, and

4.1.7 Quantity - Total weight or total length or number of pieces of each size.

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

4.2.1 Expansion test,

4.2.2 Flattening test,

4.2.3 Reverse Bend test,

4.2.4 Eddy Current test,

4.2.5 Hydrostatic test,

4.2.6 Pneumatic test,

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

- 4.2.7 Weld bead conditioning, and
- 4.2.8 Certification.

5. Materials and Manufacture

5.1 *Materials*—The material of manufacture shall be sheet or strip of UNS Alloy No. C17510 of such purity and soundness as to be suitable for processing into the products prescribed herein.

5.2 *Manufacture*—The product shall be manufactured from cold rolled strip which is subsequently formed and welded by an automatic welding process without the addition of filler metal.

6. Chemical Composition

6.1 Material shall conform to the chemical composition requirements in **Table 1** for Copper Alloy UNS No. C17510.

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

6.3 For alloys in which copper is listed as “Remainder,” copper is the difference between the sum of results of all elements determined and 100 %. When all elements in **Table 1** are determined, the sum of results shall be 99.5 % min.

7. Temper

7.1 The standard temper for products described in this specification is TF00 (Precipitation Hardened (AT)) as defined in Classification **B601**.

8. Physical Property Requirements

8.1 *Electrical Conductivity Requirement:*

8.1.1 Product furnished to this specification shall conform to the electrical conductivity requirement given in **Table 2**, when tested in accordance with Test Method **E1004**.

9. Mechanical Property Requirements

9.1 *Tensile Strength Requirements:*

9.1.1 Product furnished under this specification shall conform to the tensile and yield strength requirements prescribed in **Table 2**, when tested in accordance with Test Methods **E8/E8M**.

9.2 *Rockwell Hardness Requirements:*

9.2.1 When specified in the contract or purchase order, the product shall conform to the Rockwell hardness requirement prescribed in **Table 2** when tested in accordance with Test Methods **E18**.

9.2.2 The approximate Rockwell hardness values given in **Table 2** are for general information and assistance in testing and shall not be used as a basis for product rejection.

10. Performance Requirements

10.1 *Expansion Test:*

10.1.1 When specified in the contract or purchase order, tube specimens selected for test shall withstand an expansion of 15 % when expanded in accordance with Test Method **B153**.

10.1.2 Upon inspection, the expanded tube shall show no cracking or other defects visible to the unaided eye, but blemishes of a nature that do not interfere with the intended application are acceptable.

10.2 *Flattening Test:*

10.2.1 When specified in the contract or purchase order, the flattening test shall be performed in accordance with Test Method **B968/B968M**.

10.2.2 Upon inspection, the flattened areas of the test specimens shall be free of cracking or other defects visible to the unaided eye, but blemishes of a nature that do not interfere with the intended application are acceptable.

10.3 *Reverse Bend Test:*

10.3.1 When specified in the contract or purchase order, a reverse bend test shall be performed.

10.3.2 A section 4 in. (102 mm) in length shall be split longitudinally 90° on each side of the weld. The sample shall then be opened and bent around a mandrel with a diameter four times the wall thickness, with the mandrel parallel to the weld and on the outside of the tube. The weld when visible or identifiable shall be at the point of maximum bend.

10.3.3 Upon inspection, there shall be no evidence of cracks, or lack of penetration in the weld.

11. Other Requirements

11.1 *Eddy Current Test:*

11.1.1 Each tube shall be subjected to an eddy-current test in accordance with the procedures of Practice **E243**, except as modified in **11.1.2**. The purchaser may specify either of the tests in **11.2** or **11.3** as an alternative to the eddy-current test.

11.1.2 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 **Table 3** and **Table 4**, respectively.

11.1.2.1 The discontinuities used to calibrate the test system may be placed in the strip from which the tube will be manufactured. These calibration discontinuities will pass through the continuous operations of forming, welding, and eddy-current testing. The test unit sensitivity required to detect the resultant discontinuities shall be equivalent to or greater than that required to detect the notches or drilled holes of **Table 3** and **Table 4** respectively, or other calibration discontinuities that may be used by mutual agreement between the manufacturer or supplier and the purchaser. Calibration discontinuities may be on the outside tube surface, the internal tube surface, or

TABLE 1 Chemical Requirements

Composition, %	
Element	UNS No. C17510
Beryllium	0.2–0.6
Cobalt, max	0.3
Nickel	1.4–2.2
Iron, max	0.10
Aluminum, max	0.20
Silicon, max	0.20
Copper	Remainder

TABLE 2 Mechanical Property and Electrical Conductivity Requirements After Precipitation Heat Treatment

Temper Designation		Tensile Strength		Elongation in 2 in. (50 mm), % min	Yield Strength, ksi min, 0.2 % Offset		Rockwell Hardness B	Electrical Conductivity IACS min, %
Code	Name	ksi	MPa		ksi	MPa		
TF00	Precipitation Hardened (AT)	100–130	(690–895)	10	80	(550)	92–100	45

TABLE 3 Notch Depth

Wall Thickness, in. (mm)	Outside Diameter, in. (mm)		
	0.625 (16) to 0.750 (19), incl.	Over 0.750 (19) to 1.250 (32), incl.	Over 1.250 (32) to 2.000 (51), incl.
Over 0.017 (0.4)–0.032 (0.8)	0.005 (0.13)	0.006 (0.15)	0.007 (0.18)
Incl. 0.032 (0.8)–0.049 (1.3)	0.006 (0.15)	0.006 (0.15)	0.008 (0.20)
Incl. 0.049 (1.3)–0.083 (2.1)	0.007 (0.18)	0.008 (0.20)	0.008 (0.20)

TABLE 4 Diameter of Drilled Holes

Outside Diameter, in. (mm)	Diameter of Drilled Holes, in. (mm)	Drill No.
0.250 (6)–1.000 (25), incl.	0.031 (0.8)	68
Over 1.000 (25)–1.250 (32), incl.	0.036 (0.9)	64
Over 1.250 (32)–1.500 (38), incl.	0.042 (1.1)	58
Over 1.500 (38)–1.750 (44), incl.	0.046 (1.2)	56
Over 1.750 (44)–2.000 (51), incl.	0.052 (1.3)	55

through the tube wall and shall be spaced to provide signal resolution adequate for interpretation. Each calibration discontinuity shall be detected by the eddy-current tester.

11.1.2.2 Tubes that do not actuate the signaling device of the eddy-current tester shall be considered as conforming to the requirements of this test.

11.1.2.3 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.

11.1.2.4 Tubes causing irrelevant signals because of visible and identifiable handling marks may be retested by the hydrostatic test prescribed in 11.2, or the pneumatic test prescribed in 11.3. Tubes meeting requirements of either test shall be considered to conform if the tube dimensions are within the prescribed limits, unless otherwise agreed to by the manufacturer or supplier and the purchaser.

11.2 Hydrostatic Test:

11.2.1 When specified, each tube shall withstand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to an outer fiber stress of 7000 psi (48 MPa), determined by the following equation for thin hollow cylinders under tension. The tube need not be tested at a hydrostatic gauge pressure of over 1000 psi (7 MPa) unless otherwise specified.

$$P = 2St/(D - 0.8t) \tag{1}$$

where:

P = hydrostatic pressure, psi;

t = thickness of tube wall, in.;

D = outside diameter of the tube, in.; and

S = allowable stress of the material, psi.

11.3 Pneumatic Test:

11.3.1 When specified, each tube shall be subjected to an internal air pressure of 100 psi (0.7 MPa) gauge pressure minimum 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.

12. Dimensions, Mass, and Permissible Variations

12.1 Dimensions and tolerances for product described by this specification shall be as specified: Wall Thickness, Table 5; Diameter, Table 6; Length, Table 7; and Straightness, Table 8.

12.1.1 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.

12.2 Wall-thickness tolerances shall be in accordance with Table 5.

12.2.1 *Tubes Ordered to Minimum Wall*—No tube at its thinnest point shall be less than the specified wall thickness or greater than the specified wall thickness plus twice the tolerance values shown in Table 5.

12.2.2 *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 5.

12.3 Diameter Tolerances shall be in accordance with Table 6.

12.3.1 *Diameter*—The outside diameter 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 gauges. If no values are shown in the table, dimensions shall be as agreed between the purchaser and the manufacturer or supplier.

12.4 Length Tolerances shall be in accordance with Table 7.

TABLE 5 Wall Thickness Tolerances

Wall Thickness, in. (mm)	Outside Diameter, in. (mm)		
	0.625 (16) to 1.00 (25), incl.	Over 1.00 (25) to 2.00 (51), incl.	Over 2.00 (51) to 3.00 (76), incl.
	Wall Thickness Tolerances, Plus and Minus, in. (mm)		
0.020 (0.5) incl. to 0.032 (0.8)	0.004 (0.10)	0.004 (0.10)	0.004 (0.10)
0.032 (0.8) incl. to 0.035 (0.9)	0.004 (0.10)	0.004 (0.10)	0.005 (0.13)
0.035 (0.9) incl. to 0.058 (1.5)	0.006 (0.16)	0.006 (0.16)	0.006 (0.16)
0.058 (1.5) incl. to 0.083 (2.1)	0.008 (0.20)	0.008 (0.20)	0.008 (0.20)

TABLE 6 Diameter Tolerances

Outside Diameter, in. (mm)	Wall Thickness, in. (mm)			
	0.020 (0.05) to 0.032 (0.8), incl.	0.032 (0.8) to 0.035 (0.9), incl.	0.035 (0.9) to 0.058 (1.5), incl.	0.058 (1.5) to 0.083 (2.1), incl.
	Diameter Tolerance, Plus and Minus, in. (mm)			
0.625 (16) incl. to 0.740 (19)	0.006 (0.15)	0.006 (0.15)	0.005 (0.13)	0.005 (0.13)
0.740 (19) incl. to 1.000 (25)	0.006 (0.15)	0.006 (0.15)	0.005 (0.13)	0.004 (0.10)
1.000 (25) incl. to 1.250 (32)	0.008 (0.20)	0.008 (0.20)	0.007 (0.18)	0.006 (0.15)
1.250 (32) incl. to 1.500 (38)	0.008 (0.20)	0.008 (0.20)	0.008 (0.20)	0.007 (0.18)
1.500 (38) incl. to 3.000 (76)	0.008 (0.20)	0.008 (0.20)	0.008 (0.20)	0.008 (0.20)

TABLE 7 Length Tolerances

Specified Length, ft (m)	Tolerance, all plus, in. (mm)
Up to 30 (9.1), incl.	0.125 (3.2)
Over 30 to 60 (18.3), incl.	0.250 (6)
Over 60 to 100 (30.5), incl.	0.375 (10)

TABLE 8 Straightness Tolerances

Length, ft (m)	Maximum Curvature (Depth of Arc) in. (mm)
Over 3 (0.9) to 6 (1.8), incl.	$\frac{3}{16}$ (4.8)
Over 6 (1.8) to 8 (2.4), incl.	$\frac{5}{16}$ (7.9)
Over 8 (2.4) to 10 (3.0), incl.	$\frac{1}{2}$ (13)

12.4.1 *Length*—The length of the tubes shall not be less than that specified but may exceed the specified value by the amounts given in [Table 7](#).

12.5 *Squareness*—The departure from squareness of the end shall not exceed 0.016 in./in. (0.4 mm/mm) of diameter.

12.6 Straightness Tolerances shall be in accordance with [Table 8](#).

12.6.1 For lengths greater than 10 ft (3 m) the maximum curvature shall not exceed $\frac{1}{2}$ in. (13 mm) in any 10 ft (3 m) portion of the total length.

13. Workmanship, Finish, and Appearance

13.1 The product shall be free of defects, but blemishes of a nature that do not interfere with the intended application are acceptable.

14. Sampling

14.1 The lot size, portion size, and selection of sample pieces shall be as follows.

14.1.1 *Lot Size*—300 tubes or 15 000 ft (4600 m) or a fraction of either, whichever is less.

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

14.2 Samples taken for the purpose of 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.

15. Number of Tests and Retests

15.1 Test:

15.1.1 *Chemical Analysis*—The manufacturer shall have the option of determining conformance to chemical composition as follows: Conformance shall be determined 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:

15.1.1.1 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.

15.1.1.2 When samples are taken from the semi-finished product, a sample shall be taken to represent each 10 000 lb (4500 kg) or fraction thereof, except that not more than one sample shall be required per piece.

15.1.1.3 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.

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

15.2 Other Tests:

15.2.1 Unless otherwise provided in the product specification, test specimens shall be taken from two of the sample pieces selected in accordance with [14.1.2](#).

15.3 Retests:

15.3.1 If any test specimen shows defective machining or develops flaws, it shall be discarded and another specimen substituted.

15.3.2 If the percent 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 on an additional specimen either from the same sample piece or from a new sample piece shall be allowed.

15.3.3 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 test on both 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.