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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, which are provided for information only and are not considered standard.

1.3 *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 *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

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 information 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 and should be specified at the time of placing of the order when required:

4.2.1 Hydrostatic test,

4.2.2 Pneumatic test,

4.2.3 Weld bead conditioning, and

4.2.4 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 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.

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

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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.

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

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) as defined in Classification B601.

8. Physical Property Requirements

8.1 *Electrical Conductivity*—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 requirements prescribed in Table 2, when tested in accordance with Test Methods E8/E8M.

9.2 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.

9.2.1 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 Requirements*—Tube specimens selected for test shall withstand an expansion of 15 % when expanded in accordance with Test Method B153. This is defined as expansion of tube outside diameter in percent of original outside diameter. The expanded tube shall show no cracking or rupture visible to the unaided eye.

10.2 *Flattening Test Requirements*—Test specimens at least 4 ft in length shall be flattened on different elements throughout the length 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 visible to the unaided eye. The weld when visible or identifiable shall be placed in the position of maximum bend on one half of the flattened elements.

10.3 *Reverse Bend Test Requirements*—A section 4 in. 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. There shall be no evidence of cracks, or lack of penetration in the weld.

11. Other Requirements

11.1 Each tube shall be subjected to an eddy-current test. The purchaser may specify either of the tests in 11.2 or 11.3 as an alternative to the eddy-current test.

11.1.1 *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 E243, except as modified in 11.1.1.2.

11.1.1.1 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 Table 3 and Table 4 respectively.

11.1.1.2 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 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.

11.1.1.3 Tubes that do not actuate the signaling device of the eddy-current tester shall be considered as conforming to the

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, %
Standard	Former	ksi	MPa		ksi	MPa		
TF00	AT	100–130	(690–895)	10	80	(550)	92–100	45

TABLE 3 Notch Depth

Specified Wall Thickness, in.	Outside Diameter, in.		
	0.625 to 0.750, incl.	Over 0.750 to 1.250, incl.	Over 1.250 to 2.000, incl.
Over 0.017–0.032	0.005	0.006	0.007
Incl. 0.032–0.049	0.006	0.006	0.008
Incl. 0.049–0.083	0.007	0.008	0.008

TABLE 4 Diameter of Drilled Holes

Outside Diameter, in.	Diameter of Drilled Holes, in.	Drill No.
0.250–1.000, incl.	0.031	68
Over 1.000–1.025, incl.	0.036	64
Over 1.250–1.500, incl.	0.042	58
Over 1.500–1.750, incl.	0.046	56
Over 1.750–2.000, incl.	0.052	55

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 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*—When specified, each tube shall withstand, 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 psig unless so specified.

$$P = 2St/(D - 0.8t) \quad (1)$$

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.

11.3 *Pneumatic Test*—When specified, each tube shall be subjected to an internal air pressure of 100 psig 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 3; Diameter, Table 4; Length, Table 5; and Straightness, Table 6.

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.

TABLE 5 Wall Thickness Tolerances

Specified Wall Thickness, in.	Outside Diameter, in.		
	0.625 to 1.00, incl.	Over 1.00 to 2.00, incl.	Over 2.00 to 3.00, incl.
	Wall Thickness Tolerances, Plus and Minus, in.		
0.020 incl. to 0.032	0.004	0.004	0.004
0.032 incl. to 0.035	0.004	0.004	0.005
0.035 incl. to 0.058	0.006	0.006	0.006
0.058 incl. to 0.083	0.008	0.008	0.008

TABLE 6 Diameter Tolerances

Outside Diameter, in.	Wall Thickness, in.			
	0.020 incl. to 0.032	0.032 incl. to 0.035	0.035 incl. to 0.058	0.058 incl. to 0.083
	Diameter Tolerance, Plus and Minus, in.			
0.625 incl. to 0.740	0.006	0.006	0.005	0.005
0.740 incl. to 1.000	0.006	0.006	0.005	0.004
1.000 incl. to 1.250	0.008	0.008	0.007	0.006
1.250 incl. to 1.500	0.008	0.008	0.008	0.007
1.500 incl. to 3.000	0.008	0.008	0.008	0.008

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.

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. of diameter.

12.6 Straightness Tolerances shall be in accordance with Table 8.

12.6.1 For lengths greater than 10 ft the maximum curvature shall not exceed ½ in. in any 10-ft 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.

TABLE 7 Length Tolerances

Specified Length, ft	Tolerance, all plus, in.
Up to 30, incl.	0.125
Over 30–60, incl.	0.250
Over 60–100, incl.	0.375

TABLE 8 Straightness Tolerances

Length, ft	Maximum Curvature (Depth of Arc) in.
Over 3–6, incl	3/16
Over 6–8, incl	5/16
Over 8–10, incl	1/2

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 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 *Tests:*

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 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*—For other tests, 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 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 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 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.

16. Specimen Preparation

16.1 *Chemical Analysis*—Preparation of the analytical test specimen shall be the responsibility of the reporting laboratory (see Practice E255).

16.2 *Tensile Test*—The test specimen shall be of the full section of the tube and shall conform to the requirements of the section titled Specimens for Pipe and Tube in Test Methods E8/E8M.

16.3 *Electromagnetic (Eddy Current) Test*—Specimen preparation shall be in accordance with Practice E243.

17. Test Methods

17.1 Chemical composition shall, in cases of disagreement, be determined in accordance with the applicable method in Annex A1 of Specification B194.

17.2 *Tension Tests:*

17.2.1 Tensile specimens shall normally be tested as shown in Fig 11 of Test Methods E8/E8M. Tension test specimens shall be of the full section of the tube unless the limitations of the testing machine preclude the use of such specimen. Determination of cross sectional area shall be determined by using the weight of the tube as described in Test Methods E8/E8M.

17.2.2 Whenever different tension test results are obtained from both full-size and from machined test specimens, the results obtained from full-size test specimens shall be used to determine conformance to the requirements of this specification.

17.2.3 Tension test results on product within the scope of 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 shall not exceed 100 ksi/min (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).

18. Significance of Numerical Limits

18.1 For purpose of determining compliance with the specified limits for requirements of the properties listed in Table 9, an observed or calculated value shall be rounded as indicated, in accordance with the rounding method of Practice E29.

19. Inspection

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

TABLE 9 Rounding Units

Property	Rounded Unit for Observed or Calculated Value
Chemical composition, hardness, and electrical conductivity	Nearest unit in the last right-hand place of figures of the specified limit
Tensile strength	Nearest ksi (nearest 5 MPa)
Yield strength	Nearest ksi (nearest 5 MPa)
Elongation and expansion	Nearest 1 %

19.2 If in addition, the purchaser elects to perform the inspection, the manufacturer shall afford the inspector all reasonable facilities without charge to satisfy the purchaser that the tubes are being furnished in accordance with this specification.

20. Rejection and Rehearing

20.1 Material that fails to conform to the requirements of this specification shall be subject to rejection. Rejection shall 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.

21. Certification

21.1 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.

21.2 When material is specified to meet the requirements of ASME Boiler and Pressure Vessel Code, the certification requirements are mandatory.

22. Mill Test Report

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

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, alloy designation, temper, size, shape, gross and net weight, and name of supplier. The specification number shall be shown, when specified.

24. Keywords

24.1 condenser; copper; copper alloy; copper-beryllium; evaporator; heat exchanger; tube; welded; UNS No. C17510

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 *ASTM Standard:*

B900 Practice for Packaging of Copper and Copper Alloy Mill Products for U.S. Government Agencies

S1.1.2 *Federal Standards:*[3]

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

S1.1.3 *Military Standard:*[3]

MIL-STD-129 Marking for Shipment and Storage

S2. Quality Assurance

S2.1 *Responsibility for Inspection*—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, packed Level A, B, or C as specified in the contract or purchase order, in accordance with the arrangements of Practice B900.

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

[3] Available from DLA Document Services, Building. 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for the 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 the shipment shall be in accordance with Fed. Std. No. 123.