



Designation: B447 – 07

## Standard Specification for Welded Copper Tube<sup>1</sup>

This standard is issued under the fixed designation B447; 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 ( $\epsilon$ ) 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 establishes the requirements for welded copper tube with a longitudinal seam free of filler metal produced from sheet or strip of the following coppers:

Copper UNS Nos.	Type of Copper
C10100	Oxygen-free electronic
C10200	Oxygen-free
C10300	Oxygen-free, extra low phosphorus
C10800	Oxygen-free, low phosphorus
C11000	Electrolytic tough pitch
C12000	Phosphorus deoxidized, low residual phosphorus
C12200	Phosphorus deoxidized, high residual phosphorus
C14200	Phosphorus deoxidized, arsenical

1.2 Unless otherwise specified in the contract or purchase order, product furnished of any listed copper, with the exception of copper C11000, shall be considered acceptable.

1.2.1 Copper C11000 welded tube shall not be used in applications where hydrogen embrittlement during heating is a concern.

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

1.4 The following hazard caveat pertains only to Section 13 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 ASTM Standards:<sup>2</sup>

<sup>1</sup> 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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<sup>2</sup> 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.

- B153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing
- B170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes
- B193 Test Method for Resistivity of Electrical Conductor Materials
- B577 Test Methods for Detection of Cuprous Oxide (Hydrogen Embrittlement Susceptibility) in Copper
- B601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast
- B846 Terminology for Copper and Copper Alloys
- E3 Guide for Preparation of Metallographic Specimens
- E8 Test Methods for Tension Testing of Metallic Materials
- E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E53 Test Method for Determination of Copper in Unalloyed Copper by Gravimetry
- E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)
- E112 Test Methods for Determining Average Grain Size
- 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
- E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

### 3. Terminology

#### 3.1 Definitions:

3.1.1 For definitions of terms related to copper and copper alloys refer to Terminology B846.

#### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *lengths, mill, n*—straight lengths, including ends that are conveniently manufactured in the mills.

3.2.1.1 *Discussion*—Full-length pieces are usually 10, 12, or 20 ft and subject to established length tolerances.

3.2.2 *lengths, stock, n*—straight lengths that are mill cut and stored in advance of orders.

3.2.2.1 *Discussion*—Stock lengths are usually 6 to 20 ft and subject to established tolerances.

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

#### 4. Classification

4.1 The following types of welded tube are manufactured under this specification:

4.1.1 *As-Welded*—A condition created as a result of forming sheet or plate into tubular form and welding without subsequent heat treatment or cold work.

4.1.2 *Welded and Annealed*—Welded tube annealed to produce a uniform grain size appropriate to the specified annealed temper.

4.1.3 *Welded and Cold Drawn*—Welded tube with internal and external flash removed by scarfing or the internal flash displaced and subsequently cold drawn to conform to a specified temper.

4.1.4 *Fully Finished*:

4.1.4.1 Welded tube with internal and external flash removed by scarfing and subsequently cold drawn over a mandrel and annealed as necessary to conform to the specified temper.

4.1.4.2 Welded tube that has been mechanically worked smooth without the need for internal or external scarfing or other metal removal and subsequently cold drawn over a mandrel and annealed as necessary to conform to the specified size and temper.

#### 5. Ordering Information

5.1 Include the following information when placing orders for product under this specification, as applicable:

5.1.1 ASTM designation and year of issue,

5.1.2 Copper UNS No. designation (for example, C10300),

5.1.3 Tube type (Classification, 4),

5.1.4 Internal flash treatment (see 6.2.4),

5.1.5 Temper (Section 8),

5.1.6 Dimensions; diameter, wall thickness, length, and so forth (Section 14),

5.1.7 How furnished; straight length or coil,

5.1.8 Quantity; total weight or number of pieces or coils each copper, tube type, size, and temper, and

5.1.9 When product is purchased for electrical conductor application (Section 10).

5.2 The following are options available under this specification and shall be specified in the contract or purchase order when required:

5.2.1 Heat identification or traceability details (see 6.1.2),

5.2.2 Microscopical examination microphotographs (see 12.1),

5.2.3 Hydrogen embrittlement susceptibility test (Section 12.2),

5.2.4 Hydrostatic test (see 13.2),

5.2.5 Pneumatic test (see 13.3),

5.2.6 Certification (Section 23), and

5.2.7 Test Report (Section 24).

#### 6. Material and Manufacture

6.1 *Material*:

6.1.1 The material of manufacture shall be sheet or strip of one of the Copper UNS Nos. listed in 1.1 of such purity and soundness as to be suitable for processing into the products prescribed herein.

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

NOTE 1—Due to the discontinuous nature of the processing of castings into wrought products, it is not always practical to identify a specific casting analysis with a specific quantity of finished material.

6.2 *Manufacture*:

6.2.1 The product shall be manufactured by forming the material into a tubular shape on a suitable forming mill.

6.2.2 Welding shall be accomplished by any process that produces forge or fusion welds leaving no crevice in the weld seam visible to the unaided eye.

6.2.2.1 *Forge-Welded Tube*—The edges of the strip shall be heated to the required welding temperature, usually by a high-frequency electric current and be pressed firmly together causing a forged-type joint to be formed with internal and external flash.

6.2.2.2 *Fusion-Welded Tube*—The edges of the strip shall be brought together and welded, usually by a GTAW welding process, without the addition of filler metal, causing a fusion-type joint to be formed with no internal or external flash.

6.2.3 *Flash Removal*—The external flash of forge welded tube shall be removed by scarfing and the internal flash shall be treated by one of the following techniques:

6.2.3.1 *IFI*—Internal flash to remain in the as-welded condition.

6.2.3.2 *IFR*—Internal flash to be removed by scarfing.

6.2.3.3 *IFD*—Internal flash displaced by rolling or drawing.

6.2.4 Unless otherwise specified in the contract or purchase order, the welded tube shall be furnished with the internal flash in the IFI condition.

#### 7. Chemical Composition

7.1 The material shall conform to the chemical compositional requirements in Table 1 for the Copper UNS No. designation specified in the ordering information.

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

**TABLE 1 Chemical Requirements**

Copper UNS No.	Copper, <sup>A</sup> min	Composition, %			
		Phosphorus		Arsenic	
		Min	Max	Min	Max
C10100	99.99 <sup>B,C</sup>	...	...	...	...
C10200	99.95 <sup>D</sup>	...	...	...	...
C10300	99.95 <sup>E</sup>	0.001	0.005	...	...
C10800	99.95 <sup>E</sup>	0.005	0.012	...	...
C11000	99.90	...	...	...	...
C12000	99.90	0.004	0.012	...	...
C12200	99.9	0.015	0.040	...	...
C14200	99.4	0.015	0.040	0.15	0.50

<sup>A</sup> Copper (including silver).

<sup>B</sup> 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, zinc, phosphorus, selenium, tellurium, manganese, cadmium, and oxygen present in the sample.

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

<sup>D</sup> Oxygen in C10200 shall be 10 ppm max.

<sup>E</sup> Copper + silver + phosphorus.

8. Temper

8.1 Tempers, as defined in Classification B601, of the various tube types are as follows:

- 8.1.1 *As-Welded*:
  - 8.1.1.1 As-welded from annealed strip WM50,
  - 8.1.1.2 As-welded from half hard strip WM02, and
  - 8.1.1.3 As-welded from hard strip WM04.
- 8.1.2 *Welded and Annealed*:
  - 8.1.2.1 Welded and soft annealed W060, and
  - 8.1.2.2 Welded and light annealed W050.
- 8.1.3 *Welded and Cold Drawn*:
  - 8.1.3.1 Welded and drawn eighth hard WH00,
  - 8.1.3.2 Welded and drawn half hard WH02, and
  - 8.1.3.3 Welded and hard drawn WH04.
- 8.1.4 *Fully Finished*:
  - 8.1.4.1 Fully finished, soft annealed O60,
  - 8.1.4.2 Fully finished, light annealed O50,
  - 8.1.4.3 Fully finished, light drawn H55,
  - 8.1.4.4 Fully finished, drawn general purpose H58, and
  - 8.1.4.5 Fully finished, hard drawn H80.

9. Grain Size for Annealed Welded Tube and Annealed Fully Finished Welded Tube

9.1 Grain size shall be the standard requirement for all product in the annealed tempers.

9.2 Acceptance or rejection based upon grain size shall depend only on the average grain size of a test specimen taken from each of two sample portions, and each specimen shall be within the limits prescribed in Table 2 when determined in accordance with Test Methods E112.

10. Physical Properties

10.1 *Electrical Resistivity Requirements*:—

10.1.1 Product purchased for electrical conductor applications and when specified in the contract or purchase order, the product purchased shall conform to the electrical mass resistivity requirements in Table 3 for the copper and temper specified in the ordering information when tested in accordance with Specification B193.

NOTE 2—The International Annealed Copper Standard electrical conductivity equivalents are given in Appendix X2.

11. Mechanical Property Requirements

11.1 *Tensile Strength Requirements*:

11.1.1 As welded, welded and cold drawn, and fully finished tube in drawn tempers shall conform with the tensile

TABLE 3 Electrical Resistivity

Tempers	Electrical Resistivity, max, Ω·g/m <sup>2</sup>				
	Copper Alloy UNS Nos.				
	C10100	C10200	C10300 and C12000	C11000	C12000
Annealed	0.151 76	0.153 28	0.156 14	0.153 28	0.170 31
Drawn	0.156 14	0.157 37	0.159 40	0.157 75	0.174 18

strength requirements prescribed in Table 4 when tested in accordance with Test Methods E8.

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

11.2 *Rockwell Hardness Requirements*:

11.2.1 The approximate Rockwell hardness values given in Table 2 and Table 4 are for general information and assistance in testing and shall not be used as a basis for product rejection.

NOTE 3—The Rockwell hardness test offers a quick and convenient method for checking general conformity to the specification requirements for temper, tensile strength, and grain size.

12. Performance Requirements

12.1 *Microscopical Examination*—

12.1.1 Tubes produced of coppers C10100, C10200, C10300, and C12000 shall be free of cuprous oxide as determined by Procedure A of Test Methods B577.

12.1.2 When specified in the ordering information, microphotographs of the manufacture’s test specimens shall be provided (see 5.2.2).

12.2 *Hydrogen Embrittlement Susceptibility Test*—

12.2.1 Samples of Coppers UNS Nos. C10100, C10200, C10300, C10800, C12000, C12200, and C14200 shall be capable of passing the embrittlement test of Procedure B of Test Methods B577. The actual performance of this test is not mandatory under the terms of this specification unless specified at the time of ordering. In case of a dispute, a referee method in accordance with Procedure C shall be used.

12.3 *Expansion Test Requirements*—

12.3.1 Product in annealed tempers shall be capable of withstanding expansion in accordance with Test Method B153 to the following extent:

Outside Diameter in. (mm)	Expansion of Outside Diameter, Percent (%)
Up to ¾ (19.0) and under	40
Over ¾ (19.0)	30

12.3.2 The expanded tube area shall show no cracks or ruptures visible to the unaided eye.

TABLE 2 Property Requirements of Annealed Welded Tube and Annealed Fully Finished Welded Tube

Temper	Outside Diameter, in.	Wall Thickness, in. (mm)	Approximate Rockwell Hardness <sup>A</sup>		Average Grain Size, mm
			Scale	Value	
Soft anneal, (O60)	all	0.016 (0.406)–0.035 (0.889), incl. over 0.035 (0.889)	15T F	60 max 50 max	0.040 min 0.040 min
Light anneal, (O50)	all	0.016 (0.406)–0.035 (0.889), incl. over 0.035 (0.889)	15T F	65 max 55 max	0.040 max 0.040 max

<sup>A</sup> Rockwell hardness value shall apply only to tube having a wall thickness 0.016 in. (0.406 mm) or over and to tube having an inside diameter of 5/16 in. (7.94-mm) or over. For all other tube, no Rockwell values shall apply. Rockwell hardness tests shall be made on the inside surface of the tube. If suitable equipment is not available for determining the specified Rockwell hardness requirements in this specification, then other Rockwell scales and values shall be specified, subject to agreement between manufacturer, or supplier and purchaser. On welded and annealed tube, the Rockwell hardness test shall not be taken at the weld.

**TABLE 4 Mechanical Property Requirements of As Welded, Welded and Cold Drawn, and Fully Finished Tube in Drawn Tempers**

Temper	Outside Diameter, in. (mm)	Wall Thickness, in. (mm)	Approximate Rockwell Hardness <sup>A</sup>		Tensile Strength	
			Scale	Value	ksi <sup>B</sup>	MPa <sup>C</sup>
As-welded: WM						
WM 50 from annealed strip, (O61)	all	all	F	65 max	30 min	205 min
WM 02 from half hard strip, (HO2)	all	all	30T	43–57	36–47	250–325
WM 04 from hard strip, (HO4)	all	all	30T	54–62	45 min	310 min
Welded tube and cold drawn, WH						
WH00 welded and drawn: eighth hard	all	all	30T	30–60	36–47	250–325
WH02 welded and drawn: half hard	all	all	30T	30 min	36 min	250 min
WH04 welded and drawn: hard	¼ (6.35) to 1 (25.4), incl.	0.020 (0.508) to 0.120 (3.048) incl	30T	55 min	45 min	310 min
	over 1 (25.4) to 3½ (88.9)	0.035 (0.889) to 0.156 (3.96) incl	30T	55 min	45 min	310 min
Fully Finished Tube in Drawn Tempers						
H55 Fully Finished, light drawn	all	all	30T	30–60	36–47	250–325
H58 Fully Finished, drawn general purpose	all	all	30T	30 min	36 min	250 min
H80 Fully Finished, hard drawn	¼ (6.25) to 1 (25.4), incl.	0.020 (0.508) to 0.120 (3.048) incl	30T	55 min	45 min	310 min
	over 1 (25.4) to 3½ (88.9)	0.035 (0.889) to 0.156 (3.96) incl	30T	55 min	45 min	310 min

<sup>A</sup> Rockwell hardness values shall apply only to tube having a wall thickness of 0.020 in. (0.508 mm) or over and to tube having an inside diameter of 5/16 in. (7.94 mm) or over. Rockwell hardness tests shall be made on the inside surface of the tube. If suitable equipment is not available for determining the Rockwell hardness requirements in this specification, then other Rockwell scales and values shall be specified, subject to agreement between manufacturer, or supplier and purchaser. On as welded tube the Rockwell Hardness shall not be taken at the weld area.

<sup>B</sup> ksi = 1000 psi.

<sup>C</sup> See Appendix X1.

### 13. Other Requirements

#### 13.1 Electromagnetic (Eddy-Current) Test:

13.1.1 Each tube up to and including 3 1/8-in. (79.4-mm) outside diameter, shall be passed through an eddy-current testing unit adjusted to provide information on the suitability of the tube for the intended application.

13.1.2 Fully finished tube shall be tested in either the final drawn or annealed temper or in the drawn temper before the final anneal, unless otherwise agreed upon between the manufacturer and the purchaser.

13.1.3 Welded and annealed tube shall be tested in the as-welded condition before annealing, unless otherwise agreed upon between the manufacturer and the purchaser.

13.1.4 Each tube up to and including 3 1/8-in. (79.4-mm) outside diameter or within the capabilities of the testing unit 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.

13.1.5 Tubes that do not actuate the signaling device of the eddy current testing unit shall be considered as conforming to the requirements of this test. Testing shall follow the procedures of Practice E243, except for the determination of “end effect.”

13.1.6 For tubes greater than 3 1/8-in. (79.4 mm) in outside diameter, the manufacturer and purchaser shall agree on whatever nondestructive testing is required.

#### 13.2 Hydrostatic Test:

13.2.1 Each tube shall be capable of withstanding an internal hydrostatic pressure sufficient to subject the tube to a fiber stress of 6000 psi (41 MPa) without leakage and any leakage shall be cause for tube rejection.

#### 13.3 Pneumatic Test:

13.3.1 Each tube shall be capable of withstanding an internal air pressure of 60 psi (415 kPa) min for 5 s without leakage and any leakage shall be cause for tube rejection.

### 14. Dimensions, Mass, and Permissible Variations

14.1 The standard method for specifying tube diameters shall be with numerical fractions of an inch and for wall thickness shall be with decimal fractions of an inch.

14.2 Tolerances on a given tube shall be specified with respect to any two but not all three of the following: outside diameter, inside diameter, and wall thickness.

14.3 For purposes of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the specified limiting values for any dimension shall be cause for rejection.

NOTE 4—Blank spaces in the tolerance tables indicate either that the material is not generally available or that no tolerances have been established.

14.4 Wall Thickness Tolerances—Wall thickness of the tube shall conform to the tolerances listed in Table 5.

**TABLE 5 Wall Thickness Tolerances for Welded Tube**

Wall Thickness, in. (mm)	Outside Diameter, in. (mm) Plus and Minus	
	¼ (6.35) to 2½ (63.5)	Over 2½ (63.5) to 3½ (88.9)
0.016 (0.406) to 0.021 (0.533), incl	0.0013 (0.033)	...
Over 0.021 (0.533) to 0.026 (0.660), incl	0.0015 (0.038)	...
Over 0.026 (0.660) to 0.037 (0.940), incl	0.002 (0.051)	0.002 (0.051)
Over 0.037 (0.940) to 0.050 (1.27), incl	0.002 (0.051)	0.0025 (0.064)
Over 0.050 (1.27) to 0.073 (1.85), incl	0.0025 (0.064)	0.003 (0.076)
Over 0.073 (1.85) to 0.130 (3.30), incl	0.003 (0.076)	0.0035 (0.089)
Over 0.130 (3.30) to 0.156 (3.96), incl	0.0035 (0.089)	0.004 (0.10)