



Designation: B 447 – 02

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

This standard is issued under the fixed designation B 447; 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 approval. 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 15 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:

2.1.1 The following documents in the current issue of the *Annual Book of ASTM Standards* form a part of this specification to the extent referenced herein:

B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing<sup>2</sup>

B 170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes<sup>2</sup>

B 193 Test Method for Resistivity of Electrical Conductor Materials<sup>3</sup>

B 577 Test Methods for Detection of Cuprous Oxide (Hydrogen Embrittlement Susceptibility) in Copper<sup>2</sup>

B 601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast<sup>2</sup>

B 846 Terminology for Copper and Copper Alloys<sup>2</sup>

E 3 Guide for Preparation of Metallographic Specimens<sup>4</sup>

E 8 Test Methods for Tension Testing of Metallic Materials<sup>4</sup>

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>5</sup>

E 53 Test Methods for Determination of Copper in Unalloyed Copper by Gravimetry<sup>6</sup>

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)<sup>6</sup>

E 112 Test Methods for Determining the Average Grain Size<sup>4</sup>

E 193 Specification for Laboratory Glass Micropipets<sup>7</sup>

E 243 Practice for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes<sup>8</sup>

E 255 Practice for Sampling Copper and Copper Alloys for Determination of Chemical Composition<sup>6</sup>

### 3. Terminology

#### 3.1 Definitions:

3.1.1 For definitions of terms related to copper and copper alloys refer to Terminology B 846.

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

3.2.1 *capable of*—the test need not be performed by the manufacturer or the producer; however, if subsequent testing by the purchaser establishes that the product does not meet these requirements, the product shall be subject to rejection.

3.2.2 *flash*—the metal that protrudes at the weld, both inside and outside of the tube, as a result of the pressure applied when

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 02.01.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 02.03.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 03.01.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 14.02.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 03.06.

<sup>7</sup> *Annual Book of ASTM Standards*, Vol 14.04.

<sup>8</sup> *Annual Book of ASTM Standards*, Vol 03.03.

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

a forge-type seam is produced. The two types of flash are internal flash and external flash.

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

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

3.2.4 *lengths, multiple*—straight lengths of integral multiples of a base length, with a suitable allowance for cutting, if and when specified.

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

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

3.2.6 *scarfing*—the removal of flash by a cutting operation.

3.2.7 *tube*—a hollow product of round or any other cross section, having a continuous periphery.

#### 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 Contract or purchase orders for product under this specification shall include the following information:

5.1.1 Specification designation and year of issue,

5.1.2 Copper designation (for example, C10300),

5.1.3 Tube type (Section 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 16),

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 12.1.1),

5.2.3 Hydrogen embrittlement susceptibility test (Section 13),

5.2.4 Hydrostatic test (see 15.3),

5.2.5 Pneumatic test (see 15.4),

5.2.6 Certification (Section 25), and

5.2.7 Mill test report (Section 26).

#### 6. Material and Manufacture

6.1 *Material*:

6.1.1 The material shall be sheet or strip of the copper specified in the ordering information and shall be of such soundness as to be suitable for the production of the products described herein.

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

NOTE 1—Because of 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 welded tube shall be manufactured from either cold-rolled or annealed sheet or strip. The sheet or strip shall be formed 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 compositional requirements listed in Table 1 for the copper specified.

7.1.1 The composition limits do not preclude the presence of other elements. When limits for unnamed elements are required, they shall be established and analysis required by agreement between the manufacturer and the purchaser.

#### 8. Temper

8.1 Tempers, as defined in Classification B 601, of the various tube types are as follows:

**TABLE 1 Chemical Requirements**

Copper UNS No.	Composition, %				
	Copper, <sup>A</sup> min	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.

### 8.1.1 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. Property Requirements of Annealed Welded Tube and Annealed Fully Finished Welded Tube

9.1 The average grain size shall be within the limits specified in Table 2.

9.1.1 Grain size shall be the standard test for all annealed tempers and acceptance or rejection shall depend only upon grain size test results when tested in accordance with Test Methods E 112.

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

Temper	Outside Diameter, in.	Wall Thickness, in. (mm)	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	60 max	0.040 min
			F	50 max	
Light anneal, (O50)	all	0.016 (0.406)–0.035 (0.889), incl. over 0.035 (0.889)	15T	65 max	0.040 max
			F	55 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.

## 10. Physical Property Requirements

### 10.1 Electrical Mass Resistivity:

10.1.1 When specified in the contract or purchase order, product purchased for electrical conductor applications shall conform to the requirements of Table 3 for the copper and temper specified in the ordering information when tested in accordance with Specification E 193.

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

## 11. Mechanical Property Requirements

### 11.1 Tensile Strength:

11.1.1 As welded, welded and cold drawn, and fully finished tube in drawn tempers shall conform with the tensile strength requirements prescribed in Table 4 when tested in accordance with Test Methods E 8.

11.1.1.1 Tensile test results shall be the criteria for rejection based upon mechanical properties.

### 11.2 Rockwell Hardness:

11.2.1 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, grain size, and tensile strength.

## 12. Microscopical Examination

12.1 Tubes produced of coppers C10100, C10200, C10300, and C12000 shall be significantly free of cuprous oxide when tested in accordance with Test Method A of Test Methods B 577.

12.1.1 When specified in the ordering information, microphotographs of the manufacture's test specimens shall be provided (see 5.2.1).

## 13. Hydrogen Embrittlement Susceptibility

13.1 When specified in the ordering information, tube produced of coppers C10100, C10200, C10300, C10800, C12000, C12200, and C14200 shall be significantly free of cuprous oxide when examined in accordance with Test Method B of Test Methods B 577.

## 14. Expansion Test Requirement for Round Tube

14.1 Product in annealed tempers shall be capable of being expanded as follows when tested in accordance with Test Method B 153:

**TABLE 3 Electrical Resistivity**

Temper	Electrical Resistivity, max, $\Omega \cdot \text{g}/\text{m}^2$				
	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

Outside Diameter in. (mm)	Expansion of Outside Diameter, Percent (%)
Up to 3/4 (19.0) and under	40
Over 3/4 (19.0)	30

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

## 15. Nondestructive Testing

15.1 Each tube shall be subjected to an electromagnetic (eddy-current) examination.

15.1.1 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.

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

### 15.2 Electromagnetic (Eddy-Current) Examination:

15.2.1 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 E 243.

15.2.1.1 Tubes that do not actuate the signal device of the eddy current testing unit shall be considered as conforming to the requirements of this test.

### 15.3 Hydrostatic Test:

15.3.1 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.

### 15.4 Pneumatic Test:

15.4.1 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.

## 16. Dimensions, Mass, and Permissible Variations

16.1 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.

16.2 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.

16.3 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.

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

16.4.1 The wall thickness tolerances of tube furnished IFI listed in Table 5 shall not apply to that portion of the tube wall that contains the interior flash and weld upset.

16.4.2 The tolerances of Table 5 shall be increased by 100 % for tube furnished IFR and IFD for the portion of the tube wall that contains the weld zone.

### 16.5 Diameter Tolerances:

16.5.1 Diameter tolerances for round tubes only shall be in accordance with Table 6. For tube furnished in coils, no tolerances are established.

16.5.2 For materials furnished IFI, IFD, or IFR and not subsequently drawn over a mandrel, the inside diameter measurements shall not be taken so as to include the flash or flash-treated areas.

### 16.6 Lengths and Tolerances:

16.6.1 Tube in straight lengths shall be furnished in stock lengths with ends unless the order requires specific lengths or specific lengths with ends or tube furnished in coils.

16.6.2 The tolerances on the length for tubes furnished in straight lengths shall be in accordance with Table 7.

16.6.3 The schedule of ends for tubes furnished in specific or stock lengths with ends shall be in accordance with Table 8.

16.6.4 The tolerances for tubes furnished in coils shall be in accordance with Table 9, Table 10, and Table 11.

### 16.7 Roundness:

16.7.1 For cold-worked unannealed tube in straight lengths, the roundness tolerances shall be as shown in Table 12.

16.7.2 Compliance with the roundness tolerance shall be determined by taking measurements on the outside diameter only, irrespective of the manner in which the tube dimensions are specified.

16.7.3 The deviation from roundness is measured as the difference between major and minor diameters as determined at any one cross section of the tube.

16.7.4 No tolerances have been established for redraw tube, annealed tube, any tube furnished in coils or tube whose wall thickness is under 0.016 in. (0.406 mm).

16.8 *Squareness of Cut*—For tube in straight lengths, the departure from squareness of the end of any tube shall not exceed the following:

Specified Outside Diameter, in. (mm)	Tolerance
Up to 5/8 (15.9), incl	0.010 in. (0.25 mm)
Over 5/8 (15.9)	0.016 in./in. (0.406 mm/mm) of diameter

16.9 *Straightness Tolerances*—For tubes of any cold worked temper, 1/4 to 3 1/2 in. (6.35 to 88.9 mm) in outside diameter, inclusive, but not annealed tube, the straightness tolerances shall be in accordance with Table 13.

## 17. Workmanship, Finish, and Appearance

### 17.1 Workmanship:

17.1.1 Roundness, uniformity of the wall thickness, and inner and outer surface shall be such as to make the pipe or tube suitable for the intended applications. Unless otherwise