



## Designation: B447 – 12a (Reapproved 2021)

# 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 U.S. 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 *Units*—The values stated in inch-pound units are to be regarded as standard except for grain size, which is given in SI units. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *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.*

<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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## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- 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/E8M 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) (Withdrawn 2010)<sup>3</sup>
- 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 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.

<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.

<sup>3</sup> The last approved version of this historical standard is referenced on www.astm.org.

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

3.2.1.1 *Discussion*—Full-length pieces are usually 10 ft, 12 ft, or 20 ft (3.0 m, 3.7 m, or 6.1 m) 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 ft to 20 ft (1.8 m to 6.1 m) and subject to established tolerances.

#### 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 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 10.1).

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 (6.1.2),

5.2.2 Microscopical examination microphotographs (12.1),

5.2.3 Hydrogen embrittlement susceptibility test (Section 12.2),

5.2.4 Electrical resistivity (10.1),

5.2.5 Expansion test (12.3),

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 When specified in the contract or purchase order that 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 These 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.

#### 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*:

**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.

- 8.1.3.1 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 Property Requirements**

10.1 *Electrical Resistivity Requirements:*

10.1.1 When specified in the contract or purchase order, the product purchased for electrical conductor applications shall conform to the electrical mass resistivity requirements prescribed in **Table 3** when tested in accordance with Test Method **B193**.

**TABLE 3 Electrical Resistivity**

Tempers	Electrical Resistivity, max, $\Omega \cdot g/m^2$				
	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

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 furnished under this specification shall conform to the tensile strength requirements prescribed in **Table 4** when tested in accordance with Test Methods **E8/E8M**.

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 manufacturer'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.

**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	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  $\frac{5}{16}$  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 the manufacturer or supplier and purchaser. On as-welded tube, Rockwell Hardness shall not be taken at the weld area.

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

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

**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)

### 12.3 Expansion Test Requirements:

12.3.1 When specified in the contract or purchase order, tube furnished 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 cracking or other defects visible to the unaided eye.

## 13. Other Requirements

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

13.1.1 Each tube up to and including 3½ 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 3½ 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.

14.4.1 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.

14.4.2 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.

14.5 *Diameter Tolerances:*

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

14.5.2 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.

14.6 *Lengths and Tolerances:*

14.6.1 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.

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

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

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

14.7 *Roundness:*

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

14.7.2 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.

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

14.7.4 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).

TABLE 6 Average Diameter Tolerances

NOTE 1—Applicable to straight lengths only.

Specified Diameter, in. (mm)	Diameter to Which Tolerance Applies	Tolerance, Plus and Minus, in. (mm)
1/4 (6.35) to 5/8 (15.9), incl	inside or outside	0.002 (0.051)
Over 5/8 (15.9) to 1 (25.4), incl	inside or outside	0.0025 (0.064)
Over 1 (25.4) to 2 (50.8), incl	inside or outside	0.003 (0.076)
Over 2 (50.8) to 3 (76.2), incl	inside or outside	0.004 (0.10)
Over 3 (76.2) to 3 1/2 (88.9), incl	inside or outside	0.005 (0.13)

TABLE 7 Length Tolerances for Welded Tube in Straight Lengths

NOTE 1—Tolerances are all plus, if all minus tolerances are desired, use the same values, if tolerances plus and minus are desired, halve the values given.

Length	Tolerances, in. (mm) (Applicable Only to Full-Length Pieces)	
	For Major Outside Dimensions up to 1 in. (25.4 mm)	For Major Outside Dimensions Over 1 in. (25.4 mm) to 3 1/2 in. (88.9 mm)
Specific lengths:	1/32 (0.79)	
Up to 6 in. (152 mm) incl	1/16 (1.6)	
Over 6 in. (152 mm) to 2 ft (0.610 m) incl	1/16 (1.6)	3/32 (2.4)
Over 2 ft (0.610 m) to 6 ft (1.83 m) incl	3/32 (2.4)	1/8 (3.2)
Over 6 ft (1.83 m) to 14 ft (4.27 m) incl	1/4 (6.4)	1/4 (6.4)
Over 14 ft (4.27 m)	1/2 (12.7)	1/2 (12.7)
Specific lengths with ends	1 (25)	1 (25)
Stock lengths with or without ends	1 <sup>A</sup> (25)	1 <sup>A</sup> (25)

<sup>A</sup> As stock lengths are cut and placed in stock in advance of orders, departure from this tolerance is not practicable.

14.8 *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

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

15. *Workmanship, Finish, and Appearance*

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

16. *Sampling*

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

16.1.1 *Lot Size*—The lot size shall be 10 000 lb (4550 kg), or fraction thereof.

16.1.2 *Portion Size*—Sample pieces shall be taken for test purposes from each lot in accordance with the following schedule:

Number of Tubes in Lot	Number of Pieces to be Taken <sup>A</sup>
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2 % of the total number of pieces in the lot, but not to exceed 10 pieces

<sup>A</sup> Each sample piece shall be taken from a separate tube.

16.2 *Chemical Analysis:*

16.2.1 The sample shall be taken in approximately equal weight from each portion piece selected in 16.1.2 and in

**TABLE 8 Schedule of Tube Lengths (Specific and Stock)**

Major Outside Dimensions, in. (mm)	Nominal Length, ft (m)	Shortest Permissible Length, <sup>A</sup> % of Nominal Length	Maximum Permissible Weight of Ends, % of Lot Weight
¼ (6.35) 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 3½ (88.9) incl	6 (1.83) to 20 (6.10) incl	50	40

<sup>A</sup> Expressed to the nearest ½ ft (152.4 mm).

**TABLE 9 Coil Length Tolerance (Specific Lengths)**

Outside Diameter, in. (mm)	Tolerances, in. (mm), All Plus for Nominal Lengths in ft (m)	
	Up to 50 (15.2), incl	Over 50 (15.2) to 100 (30.5), incl
Up to 1½ (38.1), incl	12 (300)	24 (610)

**TABLE 10 Coil Length Tolerances (Mill Lengths)**

Outside Diameter, in. (mm)	Tolerances, % for Nominal Lengths in ft (m)	
	Up to 100 (30.5), incl	Over 100 (30.5) to 2000 (610), incl
Up to 1 (25.4) incl	5 <sup>A</sup> or 2 ft (0.61 m) whichever is greater	10 <sup>A</sup>
Over 1 (25.4) to 1½ (38.1)	5 <sup>A</sup> or 2 ft (0.61 m) whichever is greater	no tolerances established

<sup>A</sup> Expressed to the nearest 1 ft (304.8 mm).

**TABLE 11 Schedule of Mill Lengths with Ends, in Coils**

Outside Diameter, in. (mm)	Nominal Length, ft (m)	Shortest Permissible Length, % of Nominal Length	Maximum Permissible Weight of Ends, % of Lot Weight
Up to 1 (25.4), incl	up to 100 (30.5), incl	70 <sup>A</sup>	10
Over 1 (25.4) to 1½ (38.1), incl	up to 100 (30.5), incl	60 <sup>A</sup>	20
Up to 1 (25.4), incl	over 100 (30.5) to 2000 (610), incl	50	50 <sup>B</sup>

<sup>A</sup> Expressed to the nearest 1 ft (304.8 mm).

<sup>B</sup> Short pieces shall be included as follows: up to 10 % of lot weight between 50 ft (15.2 m) and one quarter of the full length and up to 40 % between one quarter and full length.

**TABLE 12 Roundness Tolerance**

t/D (Ratio of Nominal Wall Thickness to Nominal Outside Diameter)	Roundness Tolerance as Percent of Nominal 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 or 0.002 in. (0.051 mm), whichever is greater
Over 0.10	0.7 or 0.002 in. (0.051 mm), whichever is greater

accordance with Practice E255. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

16.2.2 Instead of sampling in accordance with Practice E255, the manufacturer shall have the option of determining composition by analyzing samples taken at the time castings are poured or taken from the semi-finished product. When the manufacturer determines the chemical composition during the course of manufacture, sampling of the finished product is not required.

**TABLE 13 Straightness Tolerances for Tube in Drawn Tempers**

NOTE 1—Applies to round tube in any drawn temper from ¼ in. to 3½ in. in outside diameter, incl.

Length, ft (m)	Maximum Curvature (Depth of Arc), in. (mm)
Over 3 (0.914) to 6 (1.83), incl	⅜ (4.8)
Over 6 (1.83) to 8 (2.44), incl	⅝ (7.9)
Over 8 (2.44) to 10 (3.05), incl	½ (13) in any 10 ft (3.05 m) portion
Over 10 (3.05)	

16.2.3 The number of samples taken for determining composition shall be as follows:

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

16.2.3.2 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 per piece shall be required.

**16.3 Other Tests:**

16.3.1 Specimens for all other tests shall be taken from two of the sample pieces taken in 16.1.2 and be of a convenient size to accommodate the test(s) and comply with the requirements of the product specification and test method(s).

16.3.2 In the event only one sample piece is required, all specimens shall be taken from the piece selected.

16.3.3 In the case of tube furnished in coils, a length sufficient for all necessary tests shall be cut from each coil selected for purpose of test. The remaining portion of these coils shall be included in the shipment, and the permissible variations in length on such coils shall be waived.

**17. Number of Tests and Retests**

**17.1 Tests:**

17.1.1 *Chemical Analysis*—Chemical composition shall be determined in accordance with the element mean of the results from at least two replicate analyses of the sample(s).

17.1.2 *Other Test*—Grain size, electrical resistivity, and tensile strength shall be reported as the average obtained from at least two pieces selected in 16.1.2 and each specimen must meet the requirements of the product specification.

17.1.2.1 When only one piece is to be sampled, all specimens shall be taken from the piece selected.

17.1.2.2 *Grain Size*—The average grain size of each specimen shall be the arithmetic average of at least three different fields.

17.2 Retests:

17.2.1 If the chemical analysis of the specimens prepared from samples selected in accordance with 16.1.2 fails to conform to the specified limits, analysis shall be made on a new composite sample prepared from the samples selected in accordance with 16.1.2.

17.2.2 If one of the two tests made to determine any of the mechanical or physical properties fails to meet a specified limit, this test shall be repeated on the remaining sample pieces, selected in accordance with 16.1.2 and the results of these tests shall comply with the specified requirements.

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

17.2.4 Test results for all specimens shall conform to the requirement(s) of this specification in retest, and failure to comply shall be cause for rejection.

18. Specimen Preparation

18.1 Chemical Analysis:

18.1.1 Preparation of the analytical test specimen shall be the responsibility of the reporting laboratory.

18.2 Grain Size:

18.2.1 Test specimen shall be prepared in accordance with Guide E3.

18.3 Electrical Resistivity:

18.3.1 The test specimen shall be full size and shall be the full cross section of the product it represents when possible.

18.4 Tensile Test:

18.4.1 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.

18.4.1.1 When the limitations of the testing machine preclude the use of a full section specimen, specimens conforming to Type No. 1 of Fig. 12, Tension Test Specimens for Large-Diameter Tubular Products of Test Methods E8/E8M shall be used.

18.5 Microscopical Examination:

18.5.1 The test specimen shall be prepared in accordance with Test Method A of Test Methods B577.

18.6 Hydrogen Embrittlement Susceptibility:

18.6.1 The test specimen shall be prepared in accordance with Test Method B of Test Methods B577.

18.7 Expansion (Pin Test):

18.7.1 Test specimen shall conform to the requirements of the Specimen Preparation section of Test Method B153.

19. Test Methods

19.1 The properties enumerated in this specification shall, in case of disagreement, be determined in accordance with the following applicable test methods:

19.1.1 Composition, in case of disagreement shall be determined as follows:

Element	Test Method
Copper	E53
Phosphorus	E62
Arsenic	E62

19.1.1.1 Refer to Annex A1 of Specification B170 for test methods to be followed in the determination of composition for copper C10100 and oxygen in copper C10200.

19.1.1.2 Test method(s) to be followed for the determination of element(s) resulting from contractual or purchase order agreement shall be as agreed upon between the manufacturer or supplier and purchaser.

19.2 Other Tests:

19.2.1 The product furnished shall conform to specified requirements when subjected to test in accordance with the following table:

Test	Method
Grain size	E112
Electrical resistivity	B193
Tensile strength	E8/E8M
Microscopical examination	B577; Test Method A
Hydrogen embrittlement susceptibility	B577; Test Method B
Expansion test	B153
Electromagnetic (eddy-current) examination	E243
Hydrostatic test	see 19.2.7
Pneumatic test	see 19.2.8

19.2.2 Grain Size—In case of dispute, the intercept method shall be followed.

19.2.3 Tensile Strength—Shall be determined in accordance with Test Methods E8/E8M. Whenever test results are obtained from both full-size and machined specimens and they differ, the test results from the full-size specimen shall prevail.

19.2.4 Microscopical Examination—In case of dispute, Test Method C of Test Methods B577 shall be followed.

19.2.5 Hydrogen Embrittlement Susceptibility—In case of dispute, Test Method C of Test Methods B577 shall be followed.

19.2.6 Electromagnetic (Eddy-Current) Examination:

19.2.6.1 Either notch depth or drilled hole artificial discontinuity calibration standards shall be used.

19.2.6.2 The depth of the round bottom transverse notches, rounded to the nearest 0.001 in. (0.025 mm), shall be 22 % of the wall thickness with a tolerance of ±0.0005 in. (±0.013 mm).

19.2.6.3 The diameters of the drilled holes in the artificial discontinuity calibration standard used to adjust the sensitivity of the testing unit are shown in Table 14 and shall not vary by

TABLE 14 Diameter of Drilled Holes

Tube Outside Diameter, in. (mm)	Diameter of Drilled Holes, in. (mm)	Drill Number
¼ to ¾ (6.0 to 19.0), incl	0.025 (0.635)	72
Over ¾ to 1 (19.0 to 25), incl	0.031 (0.785)	68
Over 1 to 1¼ (25 to 32), incl	0.036 (0.915)	64
Over 1¼ to 1½ (32 to 38), incl	0.042 (1.07)	58
Over 1½ to 1¾ (38 to 45), incl	0.046 (1.17)	56
Over 1¾ to 2 (45 to 50), incl	0.052 (1.32)	55