Designation: B 447 – 02

Standard Specification for Welded Copper Tube[1]

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 reapproval. A superscript epsilon (ε) 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[2]

B 170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes[2]

B 193 Test Method for Resistivity of Electrical Conductor Materials[3]

B 577 Test Methods for Detection of Cuprous Oxide (Hydrogen Embrittlement Susceptibility) in Copper[2]

B 601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast[2]

B 846 Terminology for Copper and Copper Alloys[2]

E 3 Guide for Preparation of Metallographic Specimens[4]

E 8 Test Methods for Tension Testing of Metallic Materials[4]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[5]

E 53 Test Methods for Determination of Copper in Unalloyed Copper by Gravimetry[6]

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)[6]

E 112 Test Methods for Determining the Average Grain Size[4]

E 193 Specification for Laboratory Glass Micropipets[7]

E 243 Practice for Electromagnic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes[8]

E 255 Practice for Sampling Copper and Copper Alloys for Determination of Chemical Composition[6]

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 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

[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.

Current edition approved Oct. 10, 2002. Published November 2002. Originally published as B 447 – 67. Last previous edition B 447 – 00.

[2] *Annual Book of ASTM Standards*, Vol 02.01.

[3] *Annual Book of ASTM Standards*, Vol 02.03.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] *Annual Book of ASTM Standards*, Vol 03.06.

[7] *Annual Book of ASTM Standards*, Vol 14.04.

[8] *Annual Book of ASTM Standards*, Vol 03.03.

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

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:

8.1.1 *As-Welded*:

8.1.1.1 As-welded from annealed strip WM50,

TABLE 1 Chemical Requirements

Copper UNS No.	Composition, %				
	Copper,[A] min	Phosphorus		Arsenic	
		Min	Max	Min	Max
C10100	99.99[B,C]	...	...	...	...
C10200	99.95[D]	...	...	...	...
C10300	99.95[E]	0.001	0.005	...	...
C10800	99.95[E]	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

[A] Copper (including silver).
[B] 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.
[C] 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.
[D] Oxygen in C10200 shall be 10 ppm max.
[E] Copper + silver + phosphorus.

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.

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:

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

14.1.1 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)	Rockwell Hardness[A]		Average Grain Size, mm
			Scale	Value	
Soft anneal, (O60)	all	0.016 (0.406)–0.035 (0.889), incl.	15T	60 max	0.040 min
		over 0.035 (0.889)	F	50 max	0.040 min
Light anneal, (O50)	all	0.016 (0.406)–0.035 (0.889), incl.	15T	65 max	0.040 max
		over 0.035 (0.889)	F	55 max	0.040 max

[A] 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 3 Electrical Resistivity

Tempers	Electrical Resistivity, max, Ω·g/m²				
	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

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 3⅛-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 ⅝ (15.9), incl	0.010 in. (0.25 mm)
Over ⅝ (15.9)	0.016 in./in. (0.406 mm/mm) of diameter

16.9 *Straightness Tolerances*—For tubes of any cold worked temper, ¼ to 3½ 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 specified in the contract or purchase order, the cut ends of the tubes shall be deburred by use of a rotating wire wheel or other suitable tool.

17.2 *Finish*:

17.2.1 The tube shall be free from defects, but blemishes of a nature that do not interfere with normal applications are acceptable. The tube shall be reasonable clean and free of dirt.

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)	Rockwell Hardness[A]		Tensile Strength	
			Scale	Value	ksi[B]	MPa[C]
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 (3.035) incl	30T	55 min	45 min	310 min
	over 1 (25.4) to 3½ (88.9)	0.035 (0.889) to 0.156 (3.90) incl	30T	55 min	45 min	310 min

[A] 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.
[B] ksi = 1000 psi.
[C] 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)

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)
¼ (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 3½ (88.9), incl	inside or outside	0.005 (0.13)

17.3 *Appearance*:

17.3.1 The surface finish and appearance shall be the normal quality for the copper, thickness, and temper ordered.

17.3.2 When application information is provided with the order, the surface shall be that producible for the application.

17.3.3 A superficial film of drawing lubricant or tarnish inhibitors are not prohibited unless otherwise specified.

18. Sampling

18.1 The lot size, portion size, and sample size of the finished product shall be as follows:

18.1.1 *Lot Size*—An inspection lot shall be 5000 lbs (2268 kg), or fraction thereof, subject to inspection at one time.

18.1.2 *Portion Size*—A portion shall be taken for test purposes from each lot according to the following schedule:

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 3½ 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	¼ (6.4)	¼ (6.4)
Over 14 ft (4.27 m)	½ (12.7)	½ (12.7)
Specific lengths with ends	1 (25)	1 (25)
Stock lengths with or without ends	1[A] (25)	1[A] (25)

[A] As stock lengths are cut and placed in stock in advance of orders, departure from this tolerance is not practicable.

Number of Tubes in Lot	Number of Pieces to be Taken[A]
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

[A] Each sample piece shall be taken from a separate tube.

18.2 *Chemical Analysis*:

18.2.1 The sample shall be taken in approximately equal weight from each portion piece selected in 18.1.2 and in accordance with Practice E 255. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

18.2.2 Instead of sampling in accordance with Practice E 255, the manufacturer shall have the option of determining composition by analyzing samples taken at the time castings are poured or taken from the semifinished product. When the manufacturer determines chemical composition during the

TABLE 8 Schedule of Tube Lengths (Specific and Stock)

Major Outside Dimensions, in. (mm)	Nominal Length, ft (m)	Shortest Permissible Length,[A] % 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

[A] Expressed to the nearest ½ ft.

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[A] or 2 ft (0.61 m) whichever is greater	10[A]
Over 1 (25.4) to 1½ (38.1)	5[A] or 2 ft (0.61 m) whichever is greater	no tolerances established

[A] Expressed to the nearest 1 ft.

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[A]	10
Over 1 (25.4) to 1½ (38.1), incl	up to 100 (30.5), incl	60[A]	20
Up to 1 (25.4), incl	over 100 (30.5) to 2000 (610), incl	50	50[B]

[A] Expressed to the nearest 1 ft.
[B] 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

course of manufacture, sampling of the finished product is not required.

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

18.2.3.1 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.

18.2.3.2 When samples are taken from the semifinished product, a sample shall be taken to represent each 10 000 lbs (4550 kg) or fraction thereof, except that not more than one sample per piece shall be required.

TABLE 13 Straightness Tolerances for Tube in Drawn Tempers

NOTE 1—Applies to round tube in any drawn temper from ¼ 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	3/16 (4.8)
Over 6 (1.83) to 8 (2.44), incl	5/16 (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)	

18.3 *Other Tests*:

18.3.1 Specimens for all other tests shall be taken from two of the sample pieces taken in 18.1.2 and be of a convenient size to accommodate the test(s) and comply with the requirements of the product specification and test method(s).

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

18.3.3 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.

19. Number of Tests and Retests

19.1 *Tests*:

19.1.1 *Chemical Analysis*—Chemical composition shall be determined as the per element mean of results from at least two replicate analyses of the sample(s) and the results of each replication must meet the requirements of the product specification.

19.1.2 *Other Test*—Grain size, electrical resistivity, and tensile strength shall be reported as individual test results obtained from each of two pieces selected in 18.1.2 and each specimen must meet the requirements of the product specification.

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

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

19.2 *Retests*:

19.2.1 When test results obtained by the purchaser fail to conform with the product specification requirement(s), the manufacturer or supplier shall have the option to perform a retest.

19.2.2 Retesting shall be as directed in this specification for the initial test, except the number of test specimens shall be twice that required normally for the test.

19.2.3 Test results for all specimens shall conform to the requirement(s) of this specification in retest, and failure to

comply shall be cause for lot rejection.

20. Specimen Preparation

20.1 *Chemical Analysis*:

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

20.2 *Grain Size*:

20.2.1 Test specimen shall be prepared in accordance with Guide E 3.

20.3 *Electrical Resistivity*:

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

20.4 *Tensile Test*:

20.4.1 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 E 8.

20.4.1.1 When the limitations of the testing machine preclude the use of a full section specimen, specimens conforming to Type No. 1 of Fig. 13, Tension Test Specimens for Large-Diameter Tubular Products of Test Methods E 8 shall be used.

20.5 *Microscopical Examination*:

20.5.1 The test specimen shall be prepared in accordance with Test Method A of Test Methods B 577.

20.6 *Hydrogen Embrittlement Susceptibility*:

20.6.1 The test specimen shall be prepared in accordance with Test Method B of Test Methods B 577.

20.7 *Expansion (Pin Test)*:

20.7.1 Test specimen shall conform to the requirements of the Specimen Preparation section of Test Method B 153.

21. Test Methods

21.1 *Chemical Composition*:

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

Element	Test Method
Copper	E 53
Phosphorus	E 62
Arsenic	E 62

21.1.1.1 Refer to Annex A1 of Specification B 170 for test methods to be followed in the determination of composition for copper C10100 and oxygen in copper C10200.

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

21.2 *Other Tests*—The product shall conform to all other requirements when subjected to tests in accordance with the appropriate test method as follows:

Requirement	Test Method
Grain size	E 112
Electrical resistivity	B 193
Tensile strength	E 8
Microscopical examination	Test Method A; B 577
Hydrogen embrittlement susceptibility	Test Method B; B 577
Expansion test	B 153
Electromagnetic (eddy-current) examination	E 243
Hydrostatic test	see 21.2.6
Pneumatic test	see 21.2.7

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

21.2.2 *Tensile Strength*—Shall be determined in accordance with Test Methods E 8. 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.

21.2.3 *Microscopical Examination*—In case of dispute, Test Method C of Test Methods B 577 shall be followed.

21.2.4 *Hydrogen Embrittlement Susceptibility*—In case of dispute, Test Method C of Test Methods B 577 shall be followed.

21.2.5 *Electromagnetic (Eddy-Current) Examination*:

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

21.2.5.2 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).

21.2.5.3 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 more than +0.001, −0.000 in. (+0.026, −0.000 mm) of the hole diameter specified.

21.2.5.4 Alternatively, at the option of the manufacturer, using speed insensitive eddy-current units that are equipped so that a fraction of the maximum imbalance signal will be selected, the following percent maximum imbalance signals shall be used:

Standard Tube Size, in.	Maximum Percent Imbalance Signal Magnitude
Up to ⅜, incl	0.2
½ to 2, incl	0.3
Over 2 to 3, incl	0.4

21.2.5.5 As an alternative, specimens with discontinuities used to calibrate the testing unit shall 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 testing unit sensitivity required to detect the resultant discontinuities shall be equivalent to or greater than that required to detect the notches or drilled holes.

21.2.5.6 The round bottom transverse notch calibration discontinuities shall be on the outside tube surface or inside tube surface. The discontinuities, notch or drilled hole, shall be spaced to provide signal resolution adequate for interpretation. Each calibration discontinuity shall be detected by the testing unit.

21.2.5.7 Tubes causing irrelevant signals because of moisture, soil, and like effects are not prohibited from being

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

reconditioned and retested. Such tubes, not causing output signals beyond acceptable limits, when retested to the original test parameters, shall be considered as conforming.

21.2.5.8 Tubes causing irrelevant signals because of visible and identifiable handling marks shall be retested by the hydrostatic or pneumatic test, and tubes meeting the requirements of either test shall be considered in conformance to the specification, provided the tube dimensions are within the prescribed limits, unless otherwise agreed upon by the manufacturer and the purchaser.

21.2.6 *Hydrostatic Test*—Fiber stress shall be determined by the following equation for thin hollow cylinders under tension:

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

where:

P = hydrostatic pressure, psi (MPa);
t = thickness of tube wall, in. (mm);
D = outside diameter of tube, in. (mm); and
S = allowable stress of the tube, psi (MPa).

21.2.6.1 The tube need not be tested at a hydrostatic pressure over 1000 psi (6.9 MPa) unless so specified.

21.2.7 *Pneumatic Test*—Testing shall be such as to permit easy visual detection of leakage, such as a pressure differential method or submerging the tube under water.

22. Significance of Numerical Limits

22.1 For purposes of determining compliance with the specified limits for requirements of the properties listed as follows, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Practice E 29:

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	nearest unit in the last right-hand place of figures of the specified limit
Grain size up to 0.055 mm, incl	nearest multiple of 0.005 mm
Tensile strength	nearest ksi (5 MPa)

23. Inspection

23.1 The manufacturer, or supplier, shall inspect and make tests necessary to verify that the product furnished conforms to the requirements prescribed in the product specification.

23.2 Source inspection of the product by the purchaser shall be agreed upon between the manufacturer, or supplier, and the purchaser as part of the purchase order. In which case, the nature of the facilities needed to satisfy the inspector representing the purchaser that the product is being furnished in accordance with the product specification shall be included in the agreement. All tests and the inspection shall be conducted so as not to interfere unnecessarily with the operations of the works.

23.3 When mutually agreed upon, final inspection shall be conducted simultaneously by the manufacturer or supplier and purchaser.

24. Rejection and Rehearing

24.1 *Rejection*:

24.1.1 Product that fails to conform to the requirements of the product specification when inspected or tested by the purchaser or purchaser's agent shall be rejected.

24.1.2 Rejection shall be reported to the manufacturer or supplier promptly and in writing.

24.1.3 In case of dissatisfaction with results of test upon which rejection was based, the manufacturer or supplier, at their option, shall make claim for a rehearing.

24.2 *Rehearing*:

24.2.1 As a result of product rejection, the manufacturer or supplier has the option to make a claim for a retest to be conducted by the manufacturer or supplier and the purchaser. If needed, samples of the rejected product shall be taken in accordance with the product specification and tested by both parties as directed in the specification, or, alternatively, upon agreement by both parties, an independent laboratory, when necessary, shall be selected for the tests using the test methods prescribed in the product specification.

25. Certification

25.1 When specified in the contract or purchase order, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and requirements have been met.

26. Test Report (Mill)

26.1 When specified in the contract or purchase order, a report of test results shall be furnished.

27. Packaging and Package Marking

27.1 *Packaging*—The product shall be separated by size, composition, and temper and prepared for shipment in such a manner as to acceptance by common carrier for transportation and to afford protection from normal hazards of transportation.

27.2 *Package Marking*—Each shipping unit shall be legibly marked with the purchase order number, copper designation, temper, size, shape, total length or piece count or both, gross and net weight, and name of supplier. The specification number shall be shown, when specified.

28. Keywords

28.1 copper tube; copper welded tube; welded tube

APPENDIXES

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = kg \cdot m/s^2$). The derived SI unit for pressure or stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since 1 ksi = 6 894 757 Pa, the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2.

X2. IACS CONDUCTIVITY EQUIVALENCE

Electrical Resistivity, $\Omega \cdot g/m^2$	Conductivity Percent, %	Electrical Resistivity, $\Omega \cdot g/m^2$	Conductivity Percent, %
0.151 76	101.00	0.157 75	97.16
0.153 28	100.00	0.159 40	96.16
0.156 14	98.16	0.170 31	90.00
0.157 37	97.40	0.174 18	88.00

SUMMARY OF CHANGES

Committee B05 has identified the location of selected changes to this standard since the last issue (B 447 – 00) that may impact the use of this standard.

(*1*) Sections 1.2.1, 3.2.1, 3.2.3, 19.2, and 21.2.5.7 have been modified to replace nonmandatory language with mandatory language.