



# Standard Specification for Seamless Copper Heat Exchanger Tubes With Internal Enhancement<sup>1</sup>

This standard is issued under the fixed designation B903; 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.

## 1. Scope\*

1.1 This specification establishes the requirements for seamless, internally enhanced copper tube, in straight lengths or coils, suitable for use in refrigeration and air-conditioning products or other heat exchangers.

1.2 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 Tubes for this application are manufactured from the following copper:

Copper UNS No.	Type of Metal
C12200	Phosphorized, high residual phosphorus (DHP)

1.4 The following pertains to the test method described in 15.2.4 of this specification: *This standard does not purport to address all the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

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

- B153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing
- B251 Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube
- B601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast
- B846 Terminology for Copper and Copper Alloys
- B950 Guide for Editorial Procedures and Form of Product Specifications for Copper and Copper Alloys

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.04 on Pipe and Tube.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

- 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

## 3. General Requirements

3.1 The following sections of Specification B251 constitute a part of this specification:

- 3.1.1 Workmanship, Finish, and Appearance.
- 3.1.2 Sampling.
- 3.1.3 Number of Tests and Retests.
- 3.1.4 Specimen Preparation.

3.2 In addition, when a section with a title identical to those referenced in 3.1 appears in this specification, it contains additional information which supplements those appearing in Specification B251. In case of conflict, this specification shall prevail.

## 4. Terminology

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

4.2 *Definitions of Terms Specific to This Standard*:

4.2.1 *bottom wall, n*—the wall thickness measured from the base of the enhancement to the outside surface.

4.2.2 *enhancement, adj*—a geometrical feature intentionally formed on a tube I.D. surface to improve heat transfer.

<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

## 5. Ordering Information

5.1 Include the following specified choices when placing orders for products under this specification, as applicable:

- 5.1.1 ASTM Designation number and the year of issue.
- 5.1.2 Temper (Section 8).

5.1.3 Length, diameter, wall thickness, and enhancement dimensions. Configuration of the enhanced surface shall be as agreed upon between the manufacturer, or supplier, and purchaser.

5.1.4 How furnished: straight lengths or coils.

5.1.5 Quantity—total weight or total length or number of pieces of each size.

5.2 The following options are available, but may not be included unless specified at the time of placing of the order when required:

- 5.2.1 Certification, if required (see Section 19).
- 5.2.2 Mill test report, if required (see Section 20).

## 6. Materials and Manufacture

6.1 *Material:*

6.1.1 The material of manufacture shall be cast billet, bar, tube, or so forth of Copper UNS No. C12200 of such purity and soundness as to be suitable for processing into the tubular product prescribed herein.

6.2 *Manufacture:*

6.2.1 The tube shall be manufactured by such hot-working, cold-working, and annealing processes as to produce a uniform wrought structure in the finished product.

6.2.2 The internal enhancement shall be produced by cold forming.

6.2.2.1 When annealed temper is required, the tube shall be annealed subsequent to the final cold-forming operation.

## 7. Chemical Composition

7.1 The material shall conform to the chemical composition requirements in **Table 1**.

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

## 8. Temper

8.1 *As-Fabricated Temper*—The tube is in the cold-worked condition produced by the enhancing operation.

8.2 *O (Annealed) Temper*—The temper of annealed tube shall be designated as O50 (light-anneal) or O60 (soft-anneal) (see **Table 2**). Tempers are defined in Classification **B601**.

NOTE 1—By agreement between the purchaser and manufacturer, product in special tempers may be supplied with properties as agreed upon between the purchaser and the manufacturer.

**TABLE 1 Chemical Requirements, UNS C12200**

Element	Composition, wt %
Copper (including silver)	99.9, min
Phosphorus	0.015–0.040

**TABLE 2**

Temper Designation	Average Grain Size, mm
As fabricated	—
O60	0.040 min
O50	0.040 max

## 9. Grain Size for Annealed Tempers

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

9.2 Samples of annealed temper tubes shall be examined at a magnification of 75 diameters. The grain size shall be determined in the wall beneath the ridges. The microstructure shall show complete recrystallization and shall have an average grain size within the limits specified in **Table 2**, when tested in accordance with Test Method **E112**.

## 10. Mechanical Property Requirements

10.1 *Tensile and Yield Strength Requirements:*

10.1.1 As-fabricated and O (annealed) temper tube shall conform to the mechanical properties specified in **Table 3**, when tested in accordance with Test Methods **E8/E8M**.

## 11. Performance Requirements

11.1 *Expansion Test:*

11.1.1 Specimens of annealed product shall withstand the expansion shown in **Table 4** when expanded in accordance with Test Method **B153**.

11.1.2 The expanded tube shall show no cracking or other defects visible to the unaided eye.

## 12. Other Requirements

12.1 *Nondestructive Examination for Defects:*

12.1.1 Each tube shall be subjected to an eddy-current test.

12.1.2 *Electromagnetic (Eddy-Current) Test:*

12.1.2.1 Tubes shall be tested normally in the as-fabricated temper; however, they may be tested in the annealed temper at the option of the manufacturer.

12.1.2.2 The testing shall follow the procedures specified in Practice **E243**. Unless otherwise agreed upon between the manufacturer, or supplier, and the purchaser, the manufacturer shall have the option of calibrating the test equipment using either notches or drilled holes. If agreement cannot be reached, drilled holes shall be used. Notch depth standards rounded to the nearest 0.001 in. (0.025 mm) shall be 22 % of the nominal bottom wall thickness. Drilled-hole standards shall be 0.025-in. (0.635-mm) diameter for tubes up to and including 3/4-in.

**TABLE 3 Mechanical Property Requirements of Designated Tempers**

Temper Designation	Tensile Strength, Min, ksi <sup>A</sup> (Mpa)	Yield Strength, ksi <sup>B</sup> (Mpa)	Elongation in 2 in., min %
As-fabricated	36 (245)	30 (205) min	—
O60	30 (205)	6 (40) min	40
O50	30 (205)	9–15 (60–105)	40

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

<sup>B</sup> Yield strength to be determined at 0.5 % extension under load.

**TABLE 4 Expansion of Annealed Product**

Outside Diameter, in. (mm)	Expansion of Outside Diameter, %
¾ (19.0) and under	30
Over ¾ (19.0)	20

specified diameter and 0.031-in. (0.785-mm) diameter for tubes over ¾-in. specified diameter.

12.1.2.3 Tubes that do not actuate the signaling device on the eddy-current tester shall be considered as conforming to the requirements of this test.

12.1.2.4 Tubes, rejected for irrelevant signals because of moisture, soil, and like effects, may be reconditioned and retested.

12.1.2.5 Tubes that are reconditioned and retested (see 12.1.2.4) shall be considered to conform to the requirements of this specification, if they do not cause output signals beyond the acceptable limits.

12.1.2.6 Eddy-current discontinuities will be identified on coils in excess of 200 ft (6096 cm) in length for subsequent removal by the purchaser.

12.1.2.7 At the customer’s discretion, the permissible number of identified eddy-current discontinuities may be specified.

**12.2 Cleanness Requirements:**

12.2.1 The tube shall be capable of meeting the following cleanliness requirement:

12.2.1.1 The inside of the tube with closed ends shall be sufficiently clean so that when the interior of the tube is washed with a suitable solvent, such as redistilled chloroform or redistilled trichloroethylene, the residue remaining upon evaporation of the solvent shall not exceed 0.0035 g/ft<sup>2</sup> (0.038 g/m<sup>2</sup>) of interior surface. See 15.2.4 for the test method.

12.2.1.2 The term “capable of” in the context of this requirement shall mean that the testing and reporting of individual lots need not be performed by the producer of the product, if capability of the manufacturing process to meet this requirement has previously been established; however, if subsequent testing by either the producer or purchaser should establish that the product does not meet this requirement, the product shall be subject to either rejection, recall or both.

**13. Dimensions, Mass, and Permissible Variations**

13.1 The standard method for specifying tube diameters and walls shall be decimal fractions of an inch.

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

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

13.4 *Bottom Wall Thickness Tolerances*—Bottom wall thickness tolerances shall conform to the tolerances listed in Table 5.

13.5 *Diameter Tolerances*—The average diameter tolerances in Table 6 shall apply to both coils and straight lengths of product.

**TABLE 5 Bottom Wall Tolerance**

Bottom Wall Thickness, in. (mm)	Tolerance (Plus and Minus) Outside Diameter, in. (mm)	
	0.125 to 0.625 (3 to 16), incl	Over 0.625 to 1.000 (16 to 25), incl
Up to 0.017 (0.43), incl.	0.001 (0.025)	0.0015 (0.038)
Over 0.017 to 0.024 (0.43 to 0.61), incl	0.002 (0.050)	0.002 (0.050)

**TABLE 6 Average Diameter Tolerances**

Specified Diameter, in. (mm)	Tolerance, Plus and Minus, in. (mm)
0.125 to 0.625 (3 to 16), incl	0.002 (0.050)
Over 0.625 to 1.000 (16 to 25), incl	0.0025 (0.063)

**13.6 Lengths:**

13.6.1 For coil lengths, see Table 7 of this specification. If coils are produced to a specified nominal weight, no coil shall weigh less than 40 % of the nominal weight, and no more than 20 % of the coils in a lot shall weigh less than 65 % of nominal weight unless otherwise agreed upon between the manufacturer, or supplier, and purchaser.

13.6.2 The tolerances for tubes furnished in straight lengths shall be in accordance with Table 8.

**13.7 Roundness:**

13.7.1 The roundness tolerance for material in straight lengths shall be 1.5 % of the OD expressed to the nearest 0.001 in. (0.025 mm).

13.7.2 The roundness tolerance for material in coils shall be 6.5 % of the OD expressed to the nearest 0.001 in. (0.025 mm).

13.8 *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 0.625 (15.9), incl.	0.010 in. (0.25 mm)
Over 0.625 (15.9)	0.016 in./in. (0.406 mm/mm)

13.9 *Straightness*—For tubes in any as fabricated temper, the straightness tolerance shall be in accordance with Table 9.

**14. Specimen Preparation**

**14.1 Chemical Analysis:**

14.1.1 Sample preparation shall be in accordance with Practice E255.

14.1.2 Analytical specimen preparation shall be the responsibility of the reporting laboratory.

**TABLE 7 Coil Length Tolerances (Specific Lengths)**

Tube Outside Diameter, in. (mm)	Nominal Length, ft (m)	Shortest Permissible Length, % of Nominal Length	Maximum Permissible Weight of Ends, % of Lot Weight	Tolerance All Plus, ft (m)
All sizes	Up to 100 (30.5), incl.	100	0	1 (0.3)
All sizes	Over 100 (30.5)	40	20	...

**TABLE 8 Length Tolerances for Straight Lengths**

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

Length	Tolerance, in. (mm)
Up to 6 in. (152 mm), incl.	1/16 (1.6)
Over 6 in. (152 mm) to 2 ft (610 m), incl.	1/16 (1.6)
Over 2 ft (610 m) to 6 ft (1.83 m), incl.	3/32 (2.38)
Over 6 ft (1.83 m) to 14 ft (4.27 m)	1/4 (6.3)
Over 14 ft (1.83 m)	1/2 (12.7)

**TABLE 9 Straightness Tolerance for Tubes**

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.	1/2 (13)
Over 10 (3.05)	1/2 (13) in any 10-ft (3.05-m) section

14.2 *Tensile Tests*—Because some internal-enhancement configurations may cause breakage of the specimen in the grips, specimen ends may be flattened and tested using wedge or sheet metal grips.

14.3 *Grain-Size*—The test specimen shall be prepared in accordance with Test Method **E3** and shall be a radial longitudinal section of the tube.

14.4 *Expansion Test Specimen*—Test specimens shall conform to the requirements of the specimen preparation section of Test Method **B153**.

14.5 *Cleanliness Test Specimen*—A section of straight tube, or a section of a straightened tube from the outside end of a coil, not less than 5 ft (1.5 m), shall be selected.

## 15. Test Methods

### 15.1 Chemical Analysis:

15.1.1 In case of disagreement, test methods for chemical analysis shall be subject to agreement between the manufacturer or the supplier and the purchaser.

15.1.2 The following table is a list of published methods, some of which may no longer be viable, which along with others not listed, may be used subject to agreement.

Element	ASTM Test Method
Copper	<b>E53</b>
Phosphorus	<b>E62</b>

15.1.3 Test methods to be followed for the determination of elements resulting from contractual or purchase order agreement shall be as agreed upon between the manufacturer or supplier and the purchaser.

### 15.2 Other Tests:

15.2.1 The product furnished shall conform to specified requirements when subjected to test in accordance with the ASTM test methods listed in **Table 10**.

#### 15.2.2 Tension Tests:

15.2.2.1 Tensile specimens shall normally be tested as shown in Fig. 11 of Test Methods **E8/E8M**. Tension test specimens shall be of the full section of the tube unless the limitations of the testing machine precludes the use of such

**TABLE 10 Methods of Test**

Test	ASTM Designation
Tension	<b>E8/E8M</b>
Grain size	<b>E112</b>
Expansion (pin test)	<b>B153</b>
Eddy current	<b>E243</b>

specimen. Determination of cross-sectional area shall be determined by using the weight of the tube as described in Test Methods **E8/E8M**.

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

15.2.2.3 Tension test results on material covered by this specification are not seriously affected by variations in speed of testing. A considerable range of testing speed is permissible; however, the rate of stressing to the yield strength should not exceed 100 ksi/min (690 MPa/min). Above the yield strength, the movement per minute of the testing machine head under load should not exceed 0.5 in./in. (0.5 mm/mm) of gage length (or distance between grips for full-section specimens).

15.2.3 *Grain-Size*—In case of dispute, the intercept procedure shall be used.

#### 15.2.4 Cleanliness Test:

15.2.4.1 A section of straight tube, or a section of a straightened tube from the outside end of a coil, not less than 5 ft (1.5 m), shall be selected. One end of the tube shall be closed and the tube shall be filled with solvent to 1/8 of capacity. The opposite end shall be closed and the tube shall be rolled back and forth on horizontal supports to wash the inside surface thoroughly. The closure shall be removed and the solvent shall be poured into a suitable weighed container. The solvent in the container shall be evaporated to dryness on a low-temperature hot plate or sand bath. Overheating of the container shall be avoided to prevent charring of the residue. The container shall then be dried in an oven at 100 to 110°C for 10 min, cooled in a desiccator, and weighed. A blank determination shall be run with the same volume of solvent and the gain in weight for the blank shall be subtracted from the weight of the residue sample. The corrected weight shall then be calculated in grams of residue per internal area of the tube in square feet.

15.2.4.2 The quantity of the solvent used will vary with the size of the tube being examined. The quantity of solvent used for the blank run shall be the same as that used for cleaning the tube sample.

15.2.4.3 The sample must be prepared in such a manner as to prevent the inclusion in the residue of copper chips or dust resulting from the cutting of the sample.

## 16. Significance of Numerical Limits

16.1 For purpose of determining compliance with the specified limits for requirements of the properties listed in **Table 11**, an observed or calculated value shall be rounded as indicated, in accordance with the rounding method of Practice **E29**.

**TABLE 11 Rounding Units**

Property	Rounded Unit for Observed or Calculated Value
Chemical composition and hardness	Nearest unit in the last right-hand place of figures of the specified limit
Tensile strength	Nearest ksi (nearest 5 MPa)
Expansion	Nearest 1 %
Grain size:	
Up to 0.055 mm incl.	Nearest multiple of 0.005 mm
Over 0.055 to 0.160 mm incl.	Nearest 0.01 mm

## 17. Inspection

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

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

## 18. Rejection and Rehearing

### 18.1 Rejection:

18.1.1 Product that fails to conform to the specification requirements when inspected or tested by the purchaser or purchaser's agent shall be subject to rejection.

18.1.2 Rejection shall be reported to the manufacturer or supplier promptly. In addition, a written notification of rejection shall follow.

18.1.3 In case of dissatisfaction with the results of the test upon which rejection is based, the manufacturer or supplier shall have the option to make claim for a rehearing.

### 18.2 Rehearing:

18.2.1 As a result of product rejection, the manufacturer, or supplier, shall have the option to make claim for a retest to be conducted by the manufacturer, or supplier, and the purchaser. Samples of the rejected product shall be taken in accordance with the product specification and subjected to test by both parties using the test method(s) specified in the product specification, or alternately, upon agreement of both parties, an independent laboratory may be selected for the test(s) using the test method(s) specified in the product specification.

## 19. Certification

19.1 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 the requirements have been met.

## 20. Mill Test Report

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

## 21. Packaging and Package Marking

21.1 The material shall be separated by size, composition, and temper and prepared for shipment in such a manner as to insure acceptance by common carrier for transportation.

21.2 Each shipping unit shall be legibly marked with the purchase order number, metal or alloy designation, temper, size, gross and net weight, total length or piece count, or both, and name of supplier. The specification number shall be shown when specified.

## 22. Keywords

22.1 C12200; coils; copper tubes; heat exchanger; internally enhanced; seamless; straight lengths

## APPENDIX

### (Nonmandatory Information)

#### X1. METRIC EQUIVALENTS

X1.1 The SI unit for strength is shown in accordance with the International System of Units (SI). The derived SI unit for force is the Newton (N), which is defined as the force that when applied to a body having a mass of 1 kg gives it an acceleration of one metre per second squared ( $N = \text{kg} \cdot \text{m/s}^2$ ).

The derived SI unit for pressure or stress is the Newton per square metre ( $\text{N/m}^2$ ), which has been named the Pascal (Pa) by the General Conference on Weights and Measures. Since  $1 \text{ ksi} = 6\,894\,757 \text{ Pa}$ , the metric equivalents are expressed as megapascals (Mpa), which is the same as  $\text{MN/m}^2$  and  $\text{N/mm}^2$ .

**SUMMARY OF CHANGES**

Committee B05 has identified the location of selected changes to this standard since the last issue (B903 – 10) that may impact the use of this standard. (Approved Oct. 1, 2015.)

(1) No technical changes have been made in this revision of the document. Minor changes to wording have been made to achieve compliance with the format and language of Guide **B950**.

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