Designation: B 903 – 00

Standard Specification for Seamless Copper Heat Exchanger Tubes With Internal Enhancement [1]

This standard is issued under the fixed designation B 903; 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.

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 The values stated in inch-pound units are the standard. SI values are given in parentheses for information only.

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 15.4 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:*

B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing[2]

B 251 Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube[2]

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

B 846 Terminology for Copper and Copper Alloys[2]

E 3 Practice for Preparation of Metallographic Specimens[3]

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 Methods for Chemical Analysis of Copper[6]

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

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

E 243 Practice for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes[7]

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

3. General Requirements

3.1 The following sections of Specification B 251 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 5.1 appears in this specification, it contains additional information which supplements those appearing in Specification B 251. In case of conflict, this specification shall prevail.

4. Terminology

4.1 *Definitions*—For the definition of terms related to copper and copper alloys refer to Terminology B 846.

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

4.1.2 *coil*, *n*—a length of the product wound into a series of connected turns.

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

4.1.4 *level wound*, *adj*—a coil in which the turns are wound into layers parallel to the axis of the coil such that successive turns in a given layer are next to one another.

4.2 *Definitions of Terms Specific to This Standard:*

4.2.1 *unaided eye*, *n*—visual inspection, without the use of special equipment or enhancement excepting the use of corrective lenses.

5. Ordering Information

5.1 Orders for products under this specification should include the following information:

5.1.1 ASTM Designation number and the year of issue.

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[1] This specification is under the jurisdiction of ASTM Committee B-05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.04 on Pipe and Tube.

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

[3] Discontinued. See 1982 *Annual Book of ASTM Standards*, Vol 03.01.

[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 03.05.

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

5.1.2 Temper.

5.1.3 Length, diameter, wall, 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 or coils.

5.1.5 Quantity.

5.1.6 Certification, if required (see Section 19).

5.1.7 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 and shall be of such purity and soundness as to be suitable for processing into the tubular product described herein.

6.2 *Manufacture*:

6.2.1 The tube shall be manufactured by such hot- and cold-working processes needed to produce a homogenous, 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 requirements specified in Table 1 as to chemical composition.

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

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 Practice B 601.

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.

9. Grain Size of Annealed Tempers

9.1 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 E 112.

10. Mechanical Properties

10.1 As-fabricated and O (annealed) temper tube shall conform to the mechanical properties specified in Table 3.

TABLE 1 Chemical Requirements, UNS C12200

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

TABLE 2

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

TABLE 3 Mechanical Property Requirements of Designated Tempers

Temper Designation	Tensile Strength, Min, ksi[A] (Mpa)	Yield Strength, ksi[B] (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

[A]ksi = 1000 psi.

[B]Yield strength to be determined at 0.5 % extension under load.

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 B 153.

11.1.2 The expanded tube shall show no cracking or rupture 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 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 E 243. 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 ¾-in. 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.

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

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 cleanness 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^2 (0.038 g/m^2) of interior surface. See 15.4 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, 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, or 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.

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*:

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)

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)

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 E 255.

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

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 E 3 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 B 153.

14.5 *Cleanness 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 In case of disagreement, the properties enumerated in this specification shall be determined in accordance with the ASTM test methods listed in Table 10.

15.2 *Tension Tests*:

15.2.1 Tensile specimens shall normally be tested as shown in Fig. 11 of Test Methods E 8. Tension test specimens shall be of the full section of the tube unless the limitations of the testing machine precludes the use of such specimen. Determination of cross-sectional area shall be determined by using the weight of the tube as described in Test Methods E 8.

15.2.2 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.

15.2.3 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).

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

15.4 *Cleanness Test*

15.4.1 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 ⅛ 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.

15.4.2 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.

15.4.3 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.

TABLE 10 Methods of Test

Test	ASTM Designation
Chemical analysis	E 53
Tension	E 8
Grain size	E 112
Expansion (pin test)	B 153
Eddy current	E 243
Phosphorus	E 62

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 E 29.

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 Product that fails to conform to the requirements of this specification when inspected or tested by the purchaser or his agent may be rejected. Rejection shall be reported to the manufacturer, or supplier. In addition, a written notification of rejection shall follow. In case of dissatisfaction with the results of the test, the manufacturer or supplier may make claim for a rehearing.

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.

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 in.	Nearest multiple of 0.005 mm
Over 0.055 to 0.160 mm incl.	Nearest 0.01 mm

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 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 ($N = kg \cdot m/s^2$). 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 megapascals (Mpa), which is the same as MN/m^2 and N/mm^2.