Designation: B68/B68M – 11

Standard Specification for Seamless Copper Tube, Bright Annealed [1]

This standard is issued under the fixed designation B68/B68M; 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 bright annealed seamless copper tube suitable for use in refrigeration, oil lines, gasoline lines, and so forth, where tube with an interior surface essentially free from scale and dirt is required.

1.1.1 Tubes made from any of the following Copper UNS No. designations shall be supplied, unless otherwise specified in the contract or purchase order:

Copper UNS No.[2]	Type of Copper
C10200	Oxygen-free without residual deoxidants
C10300	Oxygen-free, extra low phosphorus
C10800	Oxygen-free, low phosphorus
C12000	Phosphorus deoxidized, low residual phosphorus
C12200	Phosphorus deoxidized, high residual phosphorus

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *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:*[3]

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

B251M Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube (Metric)

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

B968/B968M Test Method for Flattening of Copper and Copper-Alloy Pipe and Tube

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)[4]

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)

E2575 Test Method for Determination of Oxygen in Copper and Copper Alloys

3. General Requirements

3.1 The following sections of Specification B251 or B251M are a part of this specification.

3.1.1 Terminology, General,
3.1.2 Material and Manufacture,
3.1.3 Workmanship, Finish, and Appearance,
3.1.4 Significance of Numerical Limits,
3.1.5 Inspection,
3.1.6 Rejection and Rehearing,
3.1.7 Certification,
3.1.8 Test Reports,

[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.

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[2] Refer to Practice E527 for explanation of unified numbering system (UNS).

[3] 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.

[4] 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**

3.1.9 Packaging and Package Marking, and
3.1.10 Supplementary Requirements.

3.2 In addition, when a section with an identical title to those referenced in 3.1 appears in this specification, such section may contain requirements which supersede those appearing in Specification B251 or B251M. In case of conflict, this specification prevails.

4. Terminology

4.1 *Definitions:*

4.1.1 See Terminology B846 for definitions of terms related to copper and copper alloys.

4.1.2 *bright anneal, n*—the surface obtained by annealing under conditions of controlled atmosphere to prevent oxidation and to retain the original luster of the product.

5. Ordering Information

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

5.1.1 ASTM designation and year of issue (for example, B68/B68M – 11),
5.1.2 UNS copper number (for example, C10200),
5.1.3 Temper (Section 8),
5.1.4 Dimensions, diameter, and wall thickness (Section 16),
5.1.5 How furnished: straight lengths or coils,
5.1.6 Total length, or number of pieces, of each size,
5.1.7 Total weight, each size, and
5.1.8 When product is purchased for agencies of the U.S. Government.

5.2 The following options are available and shall be specified at the time of placing the order, when required:

5.2.1 Electromagnetic (eddy-current) test,
5.2.2 Embrittlement test,
5.2.3 Expansion test,
5.2.4 Flattening test,
5.2.5 Certification, and
5.2.6 Mill test report.

6. Materials and Manufacture

6.1 *Materials:*

6.1.1 The material of manufacture shall be billets, bars, or tube of the Copper UNS No. C10200, C10300, C10800, C12000, or C12200 and shall be of such soundness as to be suitable for processing into the tubular products described.

6.2 *Manufacture:*

6.2.1 The tube shall be manufactured by such hot- or cold-working processes as to produce a homogeneous uniform wrought structure in the finished product. The tube shall be cold drawn to the finished diameter and wall thickness, and shall be bright annealed to meet the specified temper.

7. Chemical Composition

7.1 The material shall conform to the chemical composition requirements prescribed in Table 1 for the specified copper [alloy] UNS No. designation specified in the ordering information.

7.2 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 The tube shall be furnished in either of two annealed tempers as follows:

Annealed (O)	Temper Designation
O50	(Light annealed)
O60	(Soft annealed)

8.1.1 Tempers are defined in Classification B601.

9. Grain Size

9.1 Tube in the tempers O50 (light annealed) and O60 (soft annealed) shall conform to the requirements of Table 2.

10. Mechanical Property Requirements

10.1 *Tensile Strength:*

10.1.1 The tube shall have a minimum tensile strength of 30 ksi (210 MPa) when tested in accordance with Test Methods E8/E8M.

10.2 *Elongation:*

10.2.1 The tensile elongation of the tube shall be a minimum 40 % (2-in. or 50 mm gage length) when tested in accordance with Test Methods E8/E8M.

11. Performance Requirements

11.1 *Expansion Test:*

11.1.1 When specified in the contract or purchase order, the outside diameter of the tube furnished shall be capable of being expanded as follows when tested in accordance with Test Method B153.

TABLE 1 Chemical Composition

Element	Composition, %				
	Copper UNS No.				
	C10200[A]	C10300	C10800	C12000	C12200
Copper,[B] min	99.95	...	...	99.90	99.9
Copper[B] + phosphorus, min	...	99.95	99.95	...	...
Phosphorus	...	0.001–0.005	0.005–0.012	0.004–0.012	0.015–0.040

[A] Oxygen in C10200 shall be 10 ppm max. in accordance with E2575.
[B] Silver counting as copper.

TABLE 2 Average Grain Size Requirements

Temper	Grain Size, mm
O50	0.015 to 0.040
O60	0.040, min

Outside Diameter, in. (mm)	Expansion, %
¾ (19) and under	40
over ¾ (19)	30

11.1.1.1 The expanded tube shall show no cracks or ruptures seen through visual inspection without the use of special equipment or enhancement excepting the use of corrective lenses.

11.1.2 A flattening test is an optional alternative to the expansion test for annealed tube over 4 in. (100 mm) in diameter.

11.2 *Flattening Test:*

11.2.1 When specified in the contract or purchase order, the tube shall be capable of being flattened in accordance with the test method described in B968/B968M.

12. Microscopical Examination

12.1 Samples of Copper UNS Nos. C10200, C10300, and C12000 shall be free of cuprous oxide as determined by Procedure A of Test Methods B577. When Copper UNS Nos. C10800 or C12200 are supplied, examination is not required. In case of a dispute, a referee method shall be used in accordance with Procedure C of Test Methods B577.

13. Hydrogen Embrittlement

13.1 Samples of Copper UNS Nos. C10200, C12000, and C12200 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 definitely specified in the ordering information. In case of a dispute, a referee method shall be used in accordance with Procedure C of Test Methods B577.

14. Nondestructive Testing

14.1 Upon agreement between the manufacturer and the purchaser, each tube up to 3⅛ in. (80 mm) in outside diameter shall be subjected to electromagnetic (eddy-current) test. For this test, the tube shall be examined in the final drawn or annealed temper, before coiling or in straight lengths.

14.2 *Electromagnetic (Eddy-Current) Test:*

14.2.1 When examined in accordance with Practice E243, tubes that do not actuate the signaling device of the testing unit shall be considered as conforming to the requirements of the test.

15. Purchases for U.S. Government Agencies

15.1 When the contract or purchase order stipulates the purchase is for an agency of the U.S. Government, the tubes furnished shall conform to the conditions specified in the Supplementary Requirements of Specification B251 or B251M.

16. Dimensions and Permissible Variations

16.1 The dimensions and tolerances for product covered by this specification shall be as specified in the following tables and related paragraphs of Specification B251 or B251M:

16.1.1 *Wall Thickness Tolerance*—Table 1.

16.1.2 *Diameter Tolerances*—Table 3.

16.1.3 *Length Tolerances*—Tables 5 and 6.

16.1.4 *Squareness of Cut*—Refer to Squareness of Cut section 5.6.

16.2 *Coils, Length Tolerances*—Refer to Table 3, Table 4, and Table 5 of this specification.

17. Workmanship, Finish, and Appearance

17.1 *Workmanship:*

17.1.1 The tube furnished shall be clean, free of dirt, scale, and other defects, but blemishes of a nature that do not interfere with the intended application are acceptable.

17.1.2 The tube shall be bright annealed after the last drawing operation or, when required, after coiling.

17.2 *Finish and Appearance:*

17.2.1 The interior and exterior surfaces of the tube shall be typical in appearance to that of bright annealed copper.

18. Sampling

18.1 The lot size, portion size, and selection of sample portions shall be as follows:

18.1.1 *Lot Size*—The lot size shall be 10 000 lb (5000 kg) or fraction thereof.

18.1.2 *Portion Size*—Sample portions shall be selected as to be representative of the lot according to the following schedule:

Number of Pieces in Lot	Number of Sample Portions 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 portion shall be taken from a separate tube.

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

18.2 *Chemical Composition:*

TABLE 3 Coil Length Tolerances (Specific Lengths)

Tube Outside Diameter, in.	Tolerances, in., All Plus, for Nominal Lengths in Feet	
	Up to 50, incl	Over 50 to 100, incl
Up to 2, incl	12	24
Tube Outside Diameter, mm	**Tolerances, mm, All Plus, for Nominal Lengths, mm**	
	Up to 15 000, Incl.	Over 15 000 to 30 000, incl.
Up to 50, incl	300	610

TABLE 4 Coil Length Tolerances (Mill Lengths)
(Applicable only full-length pieces)

Tube Outside Diameter, in.	Tolerances, %, for Nominal Lengths in Feet	
	Up to 100, incl	Over 100 to 2000, incl
Up to 1, incl	5[A] or 2 ft, whichever is greater	10[A]
Over 1 to 2, incl	5[A] or 2 ft, whichever is greater	No tolerances established

[A] Expressed to the nearest 1 ft.

Tube Outside Diameter, mm	Tolerances, %, for Nominal Lengths, mm	
	Up to 30 000, incl	Over 30 000 to 600 000, incl
Up to 25, incl	5[A] or 600 mm, whichever is greater	10[A]
Over 25 to 50, incl	5[A] or 600 mm, whichever is greater	No tolerances established

[A] Expressed to the nearest 300 mm.

TABLE 5 Coil Schedule of Mill Lengths with Ends

Tube Outside Diameter, in.	Nominal Length, ft	Shortest Permissible Length, % of Nominal Length	Maximum Permissible Weights of Ends, % of Lot Weight
Up to 1, incl	up to 100, incl	70[A]	10
Over 1, to 2, incl	up to 100, incl	60[A]	20
Up to 1, incl	over 100 to 2000, incl	50	50[B]

[A] Expressed to the nearest 1 ft.
[B] Short pieces shall, at the option of the supplier, be included as follows: up to 10 % of lot weight between 50 ft and one quarter of full length and up to 40 % between one quarter and full length.

Tube Outside Diameter, mm	Nominal Length, mm	Shortest Permissible Length, % of Nominal Length	Maximum Permissible Weights of Ends, % of Lot Weight
Up to 25, incl	up to 30 000, incl	70[A]	10
Over 25 to 50, incl	up to 30 000, incl	60[A]	20
Up to 25, incl	over 30 000 to 60 000, incl	50	50[B]

[A] Expressed to the nearest 300 mm.
[B] Short pieces shall, at the option of the supplier, be included as follows: up to 10 % of lot weight between 15 m and one quarter of full length and up to 40 % between one quarter and full length.

18.2.1 The composite sample shall be prepared from approximate equal weights taken from the sample portions and prepared in accordance with Practice E255. The minimum weight of the composite sample shall be 150 g.

18.2.2 The manufacturer shall have the option of sampling at the time castings are poured or from the semifinished product. When composition has been determined during the manufacturing process, sampling of the finished product is not required.

18.2.3 When sampled at the time castings are poured, at least two samples shall be taken, one after the start and one near the end of the pour, for each group of castings poured simultaneously from the same source of molten metal.

18.2.4 When samples are taken from the semifinished product, a sample shall be taken to represent each 10 000 lb (5000 kg) or fraction thereof, except that not more than one sample per piece shall be required.

19. Number of Tests and Retests

19.1 *Tests:*

19.1.1 *Chemical Composition*—Shall be determined as the arithmetic mean of results from at least two replicate determinations for each specified element.

19.1.2 *Tensile, Elongation, and Grain Size*—Shall be reported as the average of results from test specimens and each specimen must conform to specification requirements.

19.1.3 *Other Tests*—At least two specimens shall be prepared for each of the other tests and each must meet test requirements.

19.2 *Retest:*

19.2.1 When test results obtained by the purchaser fail to conform to 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 for the number of test specimens which shall be twice that normally required for the test.

19.2.3 Test results for all specimens shall conform to the requirement(s) of this specification in retest. Failure to comply shall be cause for lot rejection.

20. Specimen Preparation

20.1 *Chemical Composition:*

20.1.1 Preparation of the analytical specimens for the determination of chemical composition shall be the responsibility of the reporting laboratory.

20.2 *Grain Size, Microscopical Examination, and Hydrogen Embrittlement:*

20.2.1 Test specimens shall be prepared in accordance with Guide E3.

20.2.1.1 The surface of the specimen shall approximate a radial longitudinal section of the tube.

20.3 *Tensile and Elongation Test:*

20.3.1 The test specimens shall be of the full section of the tube and shall conform to the requirements specified in the section 'Specimens for Pipe and Tube' in Test Methods E8/E8M, unless the limitations of the testing machine precludes the use of such specimens.

20.3.2 Test specimens conforming to Specimen No. 1 in Fig. 13, of Test Methods E8/E8M are acceptable for use when a full-section specimen cannot be used.

20.4 *Expansion (Pin) Test:*

20.4.1 Test specimens shall be prepared in accordance with Test Method B153.

20.5 *Flattening Test:*

20.5.1 Test specimens, 4 in. in length, shall be cut from one end of two lengths of tube. No special preparation is required.

21. Test Methods

21.1 *Chemical Analysis:*

21.1.1 In case of disagreement, chemical composition shall be determined as follows:

Element	Test Method
Copper	E53
Phosphorus	E62

21.1.2 Test method(s) for the determination of element(s) required by contractual or purchase order agreement shall be as agreed upon between the manufacturer or supplier and the purchaser.

21.2 The tubes furnished shall conform with the physical and mechanical properties and all other requirements of this specification when tested or examined in accordance with the following appropriate test method or practice:

Test	Test Method or Practice
Grain size	E112
Tensile	E8/E8M
Elongation	E8/E8M
Expansion (pin test)	B153
Microscopical examination Procedure A	B577
Hydrogen embrittlement Procedure B	B577
Flattening test	B968/B968M
Electromagnetic (eddy-current) examination	E243
Determination of Oxygen	E2575

21.2.1 *Grain Size*—In case of dispute, grain size shall be determined by the intercept method.

21.2.2 *Tensile Strength*—In case of dispute, tensile strength shall be determined in accordance with Test Methods E8/E8M.

21.2.3 *Microscopical Examination:*

21.2.3.1 Procedure A shall be followed; however, in case of dispute, Procedure C of Test Methods B577 shall be followed.

21.2.4 *Hydrogen Embrittlement:*

21.2.4.1 Procedure B shall be followed; however, in case of dispute, Procedure C of Test Methods B577 shall be followed.

21.2.5 *Electromagnetic (Eddy-Current) Test*—Each tube up to and including 3⅛ in. (80 mm) in outside diameter shall be subjected to an eddy-current test. Testing shall follow the procedures in Practice E243. Tubes shall be passed through an eddy-current test unit adjusted to provide information on the suitability of the tube for the intended application.

21.2.5.1 Either notch or drilled hole standards shall be used.

(*a*) Notch standards, rounded to the nearest 0.001 in. (0.025 mm) shall be 22 % of the wall thickness. The notch depth tolerance shall be + 0.0005 in. (+ 0.013 mm).

(*b*) Drilled holes shall be drilled radially through the wall using a suitable drill jig that has a bushing to guide the drill, care being taken to avoid distortion of the tube while drilling. The diameter of the drilled hole shall be in accordance with the following and shall not be larger than +0.001 in. (+ 0.025 mm), of the hole diameter specified.

Tube Outside Diameter, in.	Diameter of Drilled Holes, in.	Drill Number
¼ to ¾ , incl	0.025	72
Over ¾ to 1, incl	0.031	68
Over 1 to 1¼, incl	0.036	64
Over 1¼ to 1½ , incl	0.042	58
Over 1½ to 1¾ , incl	0.046	56
Over 1¾ to 2, incl	0.052	55

Tube Outside Diameter, mm	Diameter of Drilled Holes, mm	Drill Number
6.0 to 19.0, incl	0.635	72
Over 19.0 to 25, incl	0.785	68
Over 25 to 32, incl	0.915	64
Over 32 to 38, incl	1.07	58
Over 38 to 45, incl	1.17	56
Over 45 to 50, incl	1.322	55

21.2.5.2 Alternatively, at the option of the manufacturer, using speed insensitive eddy-current units that are equipped to select a fraction of the maximum imbalance signal, the following 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

Standard Tube Size, mm	Maximum Percent Imbalance Signal Magnitude
Up to 9, incl	0.2
13 to 50, incl	0.3
Over 50 to 76, incl	0.4

21.2.5.3 Tubes that do not activate the signaling device of the eddy-current tester shall be considered as conforming to the requirements of this test. Tubes with discontinuities indicated by the testing unit shall, at the option of the manufacturer, be reexamined or retested to determine whether the discontinuity is cause for rejection. Signals that are found to have been caused by minor mechanical damage, soil, or moisture, shall not be cause for rejection of the tubes provided the tube dimensions are still within prescribed limits and the tube is suitable for its intended application.

21.2.6 *Flattening Test:*

21.2.6.1 The specimen shall be slowly flattened by a press so a gage set at three times the tube wall thickness shall pass freely over the flattened section of the tube.

22. Keywords

22.1 bright annealed; copper tube; seamless tube

SUMMARY OF CHANGES

Committee B05 has identified the location of selected changes to this standard since the last issue (B68 – 02) that may impact the use of this standard. (Approved Feb. 15, 2011.)

(1) 1.2 Units section was modified.
(2) 1.3 Reference to B68M was deleted.
(3) 4.1.2 The definition for "bright anneal" was changed to agree with the one found in B846.
(4) The definition for "capable of" was removed since it is found in B846.
(5) 6.2.1 "size" was changed to "diameter."
(6) 7.1, 7.2 The wording has been changed to agree with B950 A.1, 8.1.
(7) 10.1.1 MPa value was added.
(8) In Section 11.2.1, the text for the flattening test procedure was replaced with test method B 968/B 968M.
(9) 16.1.4 Added section number.
(10) 16.2 Removed Table 2 from list.
(11) B968/B968M was also added to chart in 21.2.
(12) Test Method E2575 was added to Referenced Documents, 21.2, and Table 1 since oxygen concentration is referenced in Table 1.
(13) In Section 21.2.5.1.b, the +/- tolerance ("vary") for drilled hole diameter was changed to a plus tolerance ("not be larger than").
(14) Section 21.2.5.1.a, similar to Section 21.2.5.1.b above, the +/- notch depth tolerance was changed to a plus only (+) tolerance.
(15) 21.2.5.3 Typo was corrected.
(16) B251/B251M was changed to B251 or B251M in several places since this is not a combined document.
(17) E8 was changed to E8/E8M in several places since it is a combined document.
(18) General Requirements were placed directly below Referenced Documents.