Designation: B 360 – 95

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Specification for Hard-Drawn Copper Capillary Tube for Restrictor Applications[1]

This standard is issued under the fixed designation B 360; 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 seamless capillary tube made from Copper Alloy UNS[2] Nos. C10800, C12000, or C12200.

1.2 This tube is commonly supplied in straight lengths intended for restrictor applications such as metering lines for liquids and gases where close control over smoothness and diameter of the bore is required to insure uniform flow characteristics between tubes.

1.3 The values stated in inch pound units are the standard. Metric values in parentheses are for information only.

1.4 The following safety hazard caveat pertains only to the test method described in Section 19.3.3 (Cleanness Test) 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:*

B 251 Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube[3]

B 577 Test Methods for Hydrogen Embrittlement of Copper[3]

B 601 Practice for Temper Designation for Copper and Copper Alloys—Wrought and Cast[3]

E 3 Practice for Preparation of Metallographic Specimens[4]

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

E 53 Test Method for Chemical Analysis of Copper[5]

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)[5]

E 255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition[5]

E 527 Practice for Numbering Metals and Alloys (UNS)[6]

2.2 *ASHRAE Standard:*

No. 28-88 Method for Testing Capillary Tubes[7]

3. Terminology

3.1 *Definition:*

3.1.1 *tube, capillary, n*—a tube of small inside diameter with an inside surface of highest quality and conforming to close-diameter tolerances.

3.1.2 The tube is subject to special tests to insure precision and uniformity of bore and is specially cleaned and packed.

4. Ordering Information

4.1 The contract or purchase order for product under this specification should include the following information:

4.1.1 ASTM designation and year of issue (for example, B360 – XX),

4.1.2 Copper Alloy UNS No. (for example, C10800, Section 15 and 3),

4.1.3 Dimensions: inside and outside diameter (Table 1),

4.1.4 Air Flow requirements,

4.1.5 Quantity, total length, number of pieces or total weight of each size,

4.1.6 Length per piece of each size, and

4.1.7 When material is purchased for agencies of the U.S. Government.

4.2 The following options are available and should be specified in the contract or purchase order when required:

4.2.1 Heat Identification or traceability details,

4.2.2 Embrittlement test,

4.2.3 Certification, and

4.2.4 Mill test report.

5. Material and Manufacture

5.1 *Material*:

[1] This specification is under the jurisdiction of ASTM Committee B-5 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 E 527 for an explanation of the Unified Numbering System (UNS).

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

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

[5] *Annual Book of ASTM Standards*, Vol 03.05.

[6] *Annual Book of ASTM Standards*, Vol 01.01.

[7] Available from the American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329.

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

TABLE 1 Standard Dimensions and Residue Limits of Interior Surfaces for Capillary Tubes

Outside Diameter, in. (mm)	Inside Diameter, in. (mm)	Mean Wall Thickness, in. (mm)	Cross-Sectional Area of Tube Bore, in.^{2}(mm^2)[A]	Weight, lb/ft (kg/m)	Maximum Allowable Residue, g/linear ft (g/linear m)
0.072 (1.83)	0.026 (0.660)	0.023 (0.584)	0.0005309 (0.343)	0.01373 (0.0204)	0.00020 (0.000656)
0.072 (1.83)	0.028 (0.711)	0.022 (0.558)	0.0006158 (0.397)	0.01340 (0.0199)	0.00021 (0.000689)
0.081 (2.06)	0.031 (0.787)	0.025 (0.635)	0.0007548 (0.487)	0.01705 (0.0254)	0.00023 (0.000754)
0.081 (2.06)	0.033 (0.838)	0.024 (0.606)	0.0008553 (0.552)	0.01666 (0.0248)	0.00025 (0.000820)
0.087 (2.21)	0.036 (0.914)	0.0255 (0.648)	0.001018 (0.657)	0.01910 (0.0284)	0.00027 (0.000886)
0.087 (2.21)	0.039 (0.991)	0.024 (0.606)	0.001195 (0.771)	0.01842 (0.0239)	0.00029 (0.000951)
0.093 (2.36)	0.042 (1.07)	0.0255 (0.648)	0.001385 (0.893)	0.02096 (0.0312)	0.00032 (0.00105)
0.097 (2.47)	0.046 (1.17)	0.025 (0.648)	0.001662 (1.07)	0.02221 (0.0331)	0.00035 (0.00115)
0.099 (2.51)	0.049 (1.24)	0.025 (0.635)	0.001886 (1.22)	0.02253 (0.0335)	0.00037 (0.00121)
0.106 (2.69)	0.054 (1.37)	0.026 (0.660)	0.002290 (1.48)	0.02533 (0.0377)	0.00041 (0.00134)
0.112 (2.84)	0.059 (1.50)	0.0265 (0.673)	0.002734 (1.76)	0.02760 (0.0411)	0.00044 (0.00144)
0.125 (3.18)	0.064 (1.63)	0.0305 (0.775)	0.003217 (2.07)	0.03511 (0.0522)	0.00048 (0.00157)
0.125 (3.18)	0.070 (1.78)	0.0275 (0.698)	0.003848 (2.48)	0.03266 (0.0486)	0.00053 (0.00174)
0.125 (3.18)	0.075 (1.91)	0.025 (0.635)	0.004418 (2.85)	0.03054 (0.0454)	0.00057 (0.00187)
0.145 (3.68)	0.080 (2.03)	0.0325 (0.826)	0.005027 (3.24)	0.04453 (0.0663)	0.00060 (0.00197)
0.145 (3.68)	0.085 (2.16)	0.030 (0.762)	0.005674 (3.66)	0.04202 (0.0625)	0.00064 (0.00210)
0.145 (3.68)	0.090 (2.29)	0.0275 (0.698)	0.006362 (4.10)	0.03936 (0.0586)	0.00068 (0.00223)
0.160 (4.06)	0.100 (2.54)	0.030 (0.762)	0.007854 (5.07)	0.04750 (0.0707)	0.00075 (0.00246)
0.160 (4.06)	0.110 (2.79)	0.025 (0.635)	0.009503 (6.13)	0.04111 (0.0611)	0.00083 (0.00272)
0.188 (4.78)	0.120 (3.03)	0.034 (0.864)	0.01131 (7.29)	0.06377 (0.0949)	0.00090 (0.00295)
0.188 (4.78)	0.130 (3.30)	0.029 (0.737)	0.01327 (8.56)	0.05616 (0.0836)	0.00098 (0.00321)
0.200 (5.08)	0.145 (3.68)	0.0275 (0.698)	0.01651 (10.7)	0.05779 (0.0860)	0.00109 (0.00358)
0.220 (5.59)	0.160 (4.06)	0.030 (0.762)	0.02011 (13.0)	0.06943 (0.103)	0.00121 (0.00397)
0.240 (6.10)	0.175 (4.45)	0.0325 (0.826)	0.02405 (15.5)	0.08107 (0.121)	0.00132 (0.00433)

[A] Cross-section area of tube bore in.^{2} = (P i)(ID)^2/4 where: π = 3.1416 and ID = inside diameter.

5.1.1 The tube shall be from Copper UNS No. C10800 (oxygen free, low phosphorus), C12000 (phosphorus deoxidized, low residual phosphorus) or C12200 (phosphorus deoxidized, high residual phosphorus).

5.1.2 When heat identification or traceability is required, the details desired shall be specified in the contract or purchase order.

NOTE 1—Due to the discontinuous nature of processing castings into wrought products it is not practical to identify specific casting analysis with a specific quantity of finished product.

5.2 *Manufacture*:

5.2.1 The tube shall be produced with a continuous periphery in all stages of operation and finished by cold drawing and cleaning.

5.2.2 Process design and equipment shall be such as is required to meet the stringent requirements of the bore.

5.2.3 The tube bore shall be finished so as to be clean and smooth.

5.2.4 The outside and inside of both ends of straight lengths shall be deburred.

6. Chemical Composition

6.1 The product shall conform to the specified Copper UNS No. designation as follows:

Element, Percent	Copper UNS No. C10800	C12000	C12200
Copper	99.95[A]	99.90[B]	99.9[B]
Phosphorus	0.005–0.012	0.004–0.012	0.015–0.040

[A] Copper + Silver + Phosphorus.

[B] Silver is counted as Copper.

6.1.1 These compositional limits do not preclude the presence of other elements. Limits may be established and analysis required for un-named elements by agreement between the manufacturer and purchaser.

7. Temper

7.1 The tubes shall be furnished in the H80[8] (hard drawn) condition.

8. Mechanical Property Requirements

8.1 *Tensile Strength*:

8.1.1 The tubes shall have a tensile strength of 45 ksi (MPa 395) minimum.

9. Hydrogen Embrittlement

9.1 The material shall conform with the requirements of Procedure B of Test Methods B 577.

9.1.1 This test is not required unless specified in the contract or purchase order.

10. Cleanness Requirement

10.1 The residue attributable to the tubes shall not exceed 0.0002 g/in.^{2} (0.310 g/m^2) of internal surface of the tube when subjected to test as directed in 19.3.3 (Refer to Table 1).

11. Air Flow Requirement

11.1 The tubes shall conform with the air flow requirements stipulated at the time of order placement.

[8] Refer to Practice B 601 for definition of temper designations.

12. Purchases for U.S. Government Agencies

12.1 When purchased for agencies of the U.S. Government, the product shall conform to the conditions stipulated in the Supplementary Requirements.

13. Dimensions and Permissible Variations

13.1 *Outside Diameter Tolerance*:

13.1.1 The average outside diameter tolerance shall be± 0.002 in. (0.051 mm).

13.2 *Inside Diameter Tolerance*:

13.2.1 The average inside diameter tolerance shall be± 0.001 in. (0.025 mm) which shall be determined by the air flow test.

14. Workmanship, Finish and Appearance

14.1 Straightness, smoothness of the bore, end finish, and inner and outer surface of the tube shall be such as to make it suitable for the intended application.

14.2 The inside and outside edges of both ends of straight lengths of tube shall be free of burrs.

15. General Requirements

15.1 The following sections of Specification B 251 are a part of this specification.

15.1.1 Terminology,

15.1.2 Workmanship, Finish and Appearance,

15.1.3 Significance of Numerical Limits,

15.1.4 Inspection,

15.1.5 Rejection and Rehearing,

15.1.6 Certification,

15.1.7 Test Reports,

15.1.8 Packaging, Marking, and

15.1.9 Supplementary Requirements.

15.2 In addition, when a section with a title identical with those referenced in 15.1 appears in this specification, it contains additional requirements which supplement those appearing in Specification B 251. In case of conflict this specification shall prevail.

16. Sampling

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

16.1.1 *Lot Size*—1000 pieces, or minimum of 100 lb, or fraction thereof.

16.1.2 *Portion Size*—0.2 % of the pieces in the lot for a minimum of four pieces.

16.2 *Chemical Composition*:

16.2.1 The sample shall be taken in approximately equal weight from each portion piece selected in 16.1.2 and prepared in accordance with Practice E 255. The minimum weight of the composite sample shall be 150 g.

16.2.2 Instead of sampling in accordance with Practice E 255, the manufacturer shall have the option of sampling at the time castings are poured or taken from the semi-finished product. When the chemical composition has been determined during the course of manufacture, sampling of the finished product is not required.

16.2.3 The number of samples taken during the course of manufacture shall be as follows:

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

16.2.3.2 When samples are taken from the semi-finished product, a sample shall be taken to represent each 10 000 lb or fraction thereof, except that not more than one sample per piece shall be required.

16.3 *Other Tests*:

16.3.1 Specimens for all other tests shall be taken from two of the sample pieces taken in 16.1.2.

17. Number of Tests and Retests

17.1 *Tests*:

17.1.1 *Chemical Analysis*—Chemical composition shall be determined as the per element average of results from at least two replicate analysis of the sample and each determination must meet the specification requirements.

17.1.2 *Tensile Strength*—Shall be reported as the average results obtained from the specimen prepared from each of two pieces selected in 16.1.2.

17.1.3 Specimens for all other test must conform to specification requirements.

17.2 *Retests*:

17.2.1 When requested by the manufacturer or supplier, a retest may be permitted when test results obtained by the purchaser fail to conform with the product specification requirement(s).

17.2.2 Retesting shall be as directed in the product specification for the initial test, except for the number of test specimens which shall be twice that normally required for the test. Test results for all specimens shall conform to the product specification requirement(s) in retest and failure to comply shall be cause for lot rejection.

18. Specimen Preparation

18.1 *Chemical Analysis*:

18.1.1 Preparation of the analytical specimens shall be the responsibility of the reporting laboratory.

18.2 *Tensile Strength*:

18.2.1 The test specimen 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 E 8.

18.3 *Hydrogen Embrittlement*:

18.3.1 Test specimens shall be prepared in accordance with Procedure B of Test Methods B 577. In case of dispute, test specimens preparation shall be in accordance with Procedure C of Test Methods B 577.

19. Test Methods

19.1 Test methods used for production control or quality control, or both, for the determination of conformance with product property requirements are discretionary.

19.1.1 Test methods used to obtain data for preparation of certification or mill test report, or both, shall be made available to the purchaser upon request.

19.2 *Chemical Composition*:

19.2.1 Material composition shall be determined, in case of dispute as follows:

Element	Method
Copper	E 53
Phosphorus	E 62

19.2.2 Test method(s) used 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.

19.3 The product furnished shall conform with the physical and mechanical properties and all other requirements enumerated in this specification when tested in accordance with the following appropriate method:

Test	Method
Tensile	E 8
Hydrogen Embrittlement	E 577
Cleanness Test	Section 19.3.3
Air Flow	Section 19.3.4

19.3.1 *Tensile Strength*:

19.3.1.1 Tensile strength shall be determined as directed in procedure for small tube in Test Methods E 8.

19.3.1.2 Test results are not seriously affected by variations in speed of testing. A considerable range of testing speed is permitted; however, the rate of stressing to the yield strength should not exceed 100 ksi (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) of gage length (or distance between grips for full section specimens).

19.3.2 *Hydrogen Embrittlement*:

19.3.2.1 Procedure B shall be followed and in the case of dispute Procedure C shall be followed.

19.3.3 *Cleanness*:

19.3.3.1 In performing this test care must be exercised to clean the outside surface of the end of the sample to be immersed in the solvent. Full length samples of finished product should be tested to minimize the possibility of contamination from cutting operations for sample preparation. If full length specimens are not utilized the sample must be prepared in such a manner as to prevent the inclusion in the residue of copper chips or dust, resulting from cutting of the sample.

19.3.3.2 Using the apparatus depicted in Fig. 1, clean the interior surface of the sample with a suitable solvent (not less than 50 mL per specimen).

19.3.3.3 After collection of the solvent and residue in the vacuum flask transfer the contents of the vacuum flask to a beaker of known weight. Transfer an equivalent amount of clean solvent into a second beaker of known weight. (This is a blank to determine the contaminates in the solvent.)

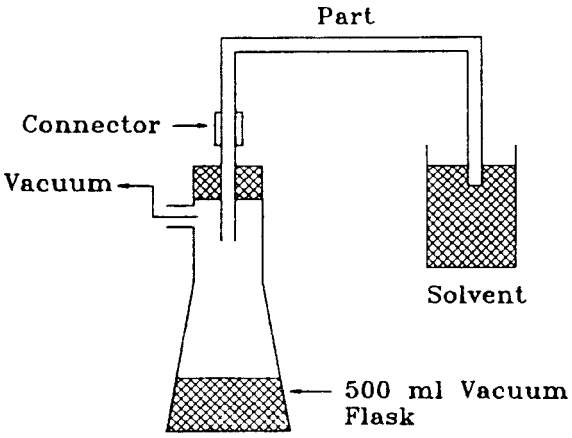

FIG. 1 Residue Extraction Apparatus

19.3.3.4 With adequate exhaust, evaporate the solvent in both beakers to near dryness on a low temperature hot plate or sandbath. **CAUTION:** Overheating may cause charring of the residue.

19.3.3.5 Place the beakers in a drying oven set at 105°± 5°C for approximately 10 min, or longer as necessary, to complete the drying process. Remove the dried containers, cool in a desiccator, and weigh.

19.3.3.6 Calculate the weight gain of the beakers by subtracting the original weight from the final weight for each.

$$\text{(Final Weight} - \text{Original Weight} = \text{Residue Weight)} \quad (1)$$

19.3.3.7 The residue per unit area is then calculated using the following formula:

$$\text{(Residue Weight of Sample} - \text{Residue Weight of Blank)/Interior Surface Area of Sample (in.}^2\text{)} \quad (2)$$

19.3.4 *Air Flow*:

19.3.4.1 Air flow shall be determined in accordance with ASHRAE Standard 28-88 after the bore has been washed with a suitable solvent.

19.3.4.2 The test method used for manufacturing quality control shall be agreed upon by the manufacturer and the purchaser.

20. Packaging and Package Marking

20.1 The tube ends shall be protected in such a manner as to prevent entrance of dust, chips or other foreign matter.

21. Keywords

21.1 capillary tube; metering tube; restrictor tube; tube

APPENDIX

(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.

SUMMARY OF CHANGES

This sections identifies the principle changes to this standard that have been incorporated since the last issue. (1) Copper alloy UNS No. C12000 has been added to the materials list, (2) Cleanness—A suitable solvent is not stated and current regulations must be reviewed when selecting the solvent.