Designation: B360 – 15

Standard Specification for Hard-Drawn Copper Capillary Tube for Restrictor Applications[1]

This standard is issued under the fixed designation B360; 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 hard-drawn, seamless capillary tube made from Copper Alloy UNS 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 *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.

1.4 *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]

B251 Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube

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

E8/E8M Test Methods for Tension Testing of Metallic Materials

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E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)[3]

E255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition

2.2 *ASHRAE Standard:*

No. 28 Method for Testing Capillary Tubes[4]

3. General Requirements

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

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

3.2 In addition, when a section with a title identical with those referenced in 3.1, above, appears in this specification, it contains additional requirements which supplement those appearing in Specification B251.

4. Terminology

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

5. Ordering Information

5.1 The contract or purchase order for product under this specification shall include the following information, as applicable:

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

5.1.2 Copper Alloy UNS No. (for example, C10800, Section 7, and Table 1),

5.1.3 Dimensions: inside and outside diameter (Table 2),

[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] 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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329, http://www.ashrae.org.

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

TABLE 1 Chemical Requirements

Element, Percent	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.

5.1.4 Air Flow requirements (ft^3/min or cfm), (see 10.3), if required.

NOTE 1—Product is specified to air flow requirements for capillary applications.

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

5.1.6 Length per piece of each size, and

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

5.2.1 Heat Identification or traceability details,

5.2.2 Embrittlement test, (see 10.1),

5.2.3 Certification, (see 3.1.6), and

5.2.4 Mill test report (see 3.1.7).

6. Material and Manufacture

6.1 *Material:*

6.1.1 The material of manufacture shall be from a cast and extruded tube of Copper Alloy UNS No. C10800 (oxygen free, low phosphorus), C12000 (phosphorus deoxidized, low residual phosphorus), or C12200 (phosphorus deoxidized, high residual phosphorus) of such purity and soundness as to be suitable for processing in to the product prescribed herein.

6.1.2 In the event heat identification or traceability is required, the purchaser shall specify the details desired.

NOTE 2—Due to the discontinuous nature of processing 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 product shall be manufactured by cold drawing processes as to produce a uniform wrought structure in the finished product.

6.2.2 The tube shall be finished by degreasing or other cleaning operations to meet the stringent requirements for cleanness of the inner diameter.

6.2.3 The outside and inside of both ends of straight lengths shall be made free of burrs that could restrict flow, by burr-free cutting, brushing, or chamfering.

6.2.4 The maximum allowable residue as determined by the cleanness test described in 16.4 shall not exceed the value given in Table 2 for the tube size tested.

7. Chemical Composition

7.1 The material shall conform to the chemical composition requirements in Table 1 for the Copper UNS Alloy No. designation specified in the ordering information.

7.1.1 Results of analysis on a product (check) sample shall conform to the composition requirements within the permitted analytical variance specified 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 un-named elements.

8. Temper

8.1 The tubes shall be furnished in the H80[5] (hard drawn) condition.

9. Mechanical Property Requirements

9.1 *Tensile Strength:*

9.1.1 The tubes shall have a tensile strength of 45 ksi (310 MPa) minimum.

10. Other Requirements

10.1 *Embrittlement Requirement:*

10.1.1 Samples of product produced from Coppers UNS Nos. C10800 and C12000 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 specified in the ordering information. In case of a dispute, a referee method in accordance with Procedure C shall be employed.

10.2 *Cleanness Requirement:*

10.2.1 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 16.4 (Refer to Table 2)

10.3 *Air Flow Requirement:*

10.3.1 When specified, the tubes shall conform to the air flow requirements, in ft^3/min [cfm] stipulated at the time of order placement, when tested in accordance with the test in 16.5.

11. Dimensions, Mass, and Permissible Variations

11.1 *Outside Diameter Tolerance:*

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

11.2 *Inside Diameter Tolerance:*

11.2.1 The average inside diameter tolerance shall be ±0.001 in. (0.025 mm) which shall be determined by pin gages, or when specified, by the air flow test. The flow rate tolerance will be agreed upon by the purchaser and manufacturer.

11.3 *Straightness:*

11.3.1 The straightness tolerance shall be in accordance with Table 3.

12. Workmanship, Finish, and Appearance

12.1 The product shall be free of defects, but blemishes of a nature that do not interfere with the intended application are acceptable.

12.2 The inside and outside edges of both ends of straight lengths of tube shall be free of burrs (see 6.2.3).

[5] Refer to Classification B601 for definition of temper designations.

TABLE 2 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} = $(\pi)(ID)^2/4$ where: π = 3.1416 and ID = inside diameter.

TABLE 3 Straightness Tolerance

Length ft (m)	Maximum Curvature (Depth of Arc) in. (mm)
Over 3 (0.914) to 6 (1.83), incl.	.188 in. (4.8)
Over 6 (1.83) to 8 (2.44), incl.	.313 in. (7.9)
Over 8 (2.44) to 10 (3.05), incl.	.500 in. (13)
Over 10 (3.05)	.500 in. (13) in any 10 ft (3.05 m) section

13. Sampling

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

13.1.1 *Lot Size*—1000 pieces, or maximum of 100 lb, or fraction thereof.

13.1.2 *Portion Size*—0.2 % of the pieces in the lot, or a minimum of four pieces, whichever is greater.

13.2 *Chemical Composition:*

13.2.1 The sample shall be taken in approximately equal weight from each portion piece selected in 13.1.2 and prepared in accordance with Practice E255. The minimum weight of the composite sample shall be 150 g.

13.2.2 Instead of sampling in accordance with Practice E255, 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.

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

13.2.3.1 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.

13.2.3.2 When samples are taken from the semi-finished product, a sample shall be taken to represent each 10 000 lb (4537 kg) or fraction thereof, except that not more than one sample per piece shall be required.

13.3 *Other Tests:*

13.3.1 Specimens for all other tests shall be taken from two of the sample pieces taken in 13.1.2.

14. Number of Tests and Retests

14.1 *Tests:*

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

14.1.2 *Tensile Strength*—Shall be reported as the average results obtained from the specimen prepared from each of two pieces selected in 13.1.2.

14.1.3 Specimens for all other tests must conform to specification requirements.

14.2 *Retests:*

14.2.1 When requested by the manufacturer or supplier, a retest shall be permitted when results of tests obtained by the purchaser fail to conform to the requirements of the product specification.

14.2.2 The retest 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 specified test.

14.2.3 All test specimens shall conform to the product specification requirement(s) in retest. Failure to comply shall be cause for rejection.

15. Specimen Preparation

15.1 *Chemical Analysis:*

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

15.2 *Tensile Strength:*

15.2.1 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 E8/E8M.

15.3 *Embrittlement:*

15.3.1 Test specimens shall be prepared in accordance with Procedure B of Test Methods B577. In case of dispute, test specimens preparation shall be in accordance with Procedure C of Test Methods B577.

15.4 *Cleanness:*

15.4.1 Full-length specimens of finished product, subsequent to cleaning, shall be selected for testing, where feasible, to minimize the possibility of contamination from cutting operations.

15.4.2 If full-length specimens can not be utilized due to size, length, or other constraints, the specimen must be prepared in such a manner as to prevent the inclusion in the residue of copper chips or dust, resulting from cutting operations.

15.4.3 In performing this test, care must be exercised to clean the outside surface of the end of the specimen to be immersed in the solvent.

15.5 *Air Flow Test:*

15.5.1 Full-length specimens of finished product shall be selected for testing.

16. Test Methods

16.1 *Chemical Analysis:*

16.1.1 In cases of disagreement, test methods for chemical analysis shall be subject to agreement between the manufacturer or supplier and the purchaser. 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	Test Method
Copper	E53
Phosphorus	E62

16.1.2 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.

16.2 *Tensile Strength:*

16.2.1 Tensile strength shall be determined as directed in procedure for small tube in Test Methods E8/E8M.

16.2.2 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/mm) of gage length (or distance between grips for full section specimens).

16.3 *Embrittlement:*

16.3.1 Procedure B of Test Method B577 shall be followed and in the case of dispute Procedure C shall be followed.

16.4 *Cleanness:*

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

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

16.4.3 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.)

16.4.4 With adequate exhaust, evaporate the solvent in both beakers to near dryness on a low temperature hot plate or sandbath. (**Warning—**Overheating may cause charring of the residue.)

16.4.5 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.

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

(Final Weight − Original Weight = Residue Weight)

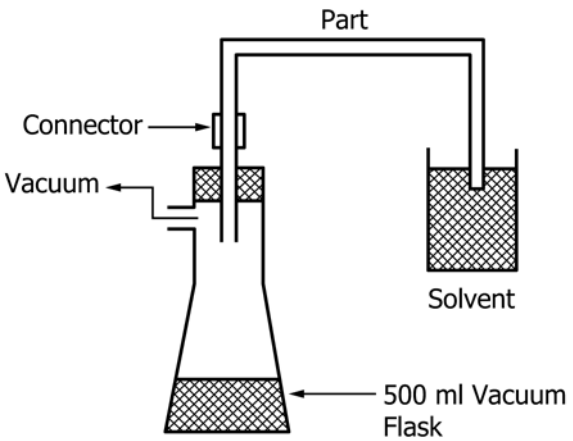

FIG. 1 Residue Extraction Apparatus

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

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

16.5 *Air Flow:*

16.5.1 Airflow shall be determined in accordance with ASHRAE Standard 28 (Current Edition) after the bore has been washed with a suitable solvent.

16.5.2 The manufacturer and the purchaser shall agree upon the test method used for manufacturing quality control.

17. Packaging and Package Marking

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

18. Keywords

18.1 C10800; C12000; C12200; capillary tube; metering tube; restrictor tube; tube

SUMMARY OF CHANGES

Committee B05 has identified the principal changes to this specification that have been incorporated since the 2009 issue as follows:

(1) 2.1 Referenced Documents, E8 is now combined document E8/E8M. This same change was also made in 15.2.1 and 16.2.1.

(2) 2.1 Referenced Documents, removed reference to B950 since Form of Product Spec. changes were performed for previous edition.

(3) Table 2 Footnote A, changed "Pi" to π symbol to be consistent within sentence.

(4) 12.2, wrong paragraph # referenced. 6.2.2 should be 6.2.3.

(5) 14.1.1, Typo – analysis should be analyses.

(6) 14.1.3, Typo – test should be tests.

(7) 16.1, 16.1.1, and 16.1.2 – Changed wording to reflect standard wording from B950 *Guide for Editorial Procedures and Form of Product Specifications for Copper and Copper Alloys*.