EXHIBIT 150
PART 4

CERTIFICATE

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By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name:

CFR Section(s):

Standards Body:

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 557 – 84

Standard Methods of TENSION TESTING WROUGHT AND CAST ALUMINUM- AND MAGNESIUM-ALLOY PRODUCTS[1]

This standard is issued under the fixed designation B 557; 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.

These methods have been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 These methods cover the tension testing of wrought and cast aluminum- and magnesium-alloy products, excepting aluminum foil.[2]

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—Exceptions to the provisions of these methods may need to be made in individual specifications or test methods for a particular material.

NOTE 2—A complete metric companion to Methods B 557 has been developed—Methods B 557M; therefore, no metric equivalents are presented in these methods.

2. Applicable Documents

2.1 The following documents of the issue in effect on the date of material purchase form a part of this specification to the extent referenced herein:

2.1.1 *ASTM Standards*:

E 4 Methods of Load Verification of Testing Machines[3]

E 6 Definitions of Terms Relating to Methods of Mechanical Testing[4]

E 8 Methods of Tension Testing of Metallic Materials[4]

E 29 Recommended Practice for Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values[5]

E 83 Method of Verification and Classification of Extensometers[4]

E 345 Methods of Tension Testing of Metallic Foil[4]

3. Significance

3.1 Tension tests provide information on the strength and ductility of materials under uniaxial tensile stresses. This information may be useful in comparisons of materials, alloy development, quality control, and design under certain circumstances.

3.2 The results of tension tests of specimens machined to standardized dimensions from selected portions of a part or material may not totally represent the strength and ductility properties of the entire end product or its in-service behavior in different environments.

3.3 For quality control purposes, results derived from standardized tension test specimens can be considered to be indicative of the response of the material from which they were taken to processing and heat treatment.

4. Definitions

4.1 The definitions of terms relating to tension testing appearing in Definitions E 6 shall be considered as applying to the terms used in these methods.

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[1] These methods are under the jurisdiction of ASTM Committee B-7 on Light Metals and Alloys and are the direct responsibility of Subcommittee B07.05 on Testing.

Current edition approved Feb. 24, 1984. Published April 1984. Originally published as B 557 – 71. Last previous edition B 557 – 81.

[2] For methods of tension testing of aluminum foil, see Methods E 345.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

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

[5] *Annual Book of ASTM Standards*, Vol 14.02.

5. Apparatus

5.1 *Testing Machines*:

5.1.1 Machines used for tension testing shall conform to the requirements of Methods E 4. The loads used in determining tensile strength and yield strength shall be within the loading range of the testing machine as defined in Methods E 4.

5.2 *Gripping Devices*:

5.2.1 *General*—Various types of gripping devices may be used to transmit the measured load applied by the testing machine to the test specimens. To ensure axial tensile stress within the gage length, the axis of the test specimen must coincide with the center line of the heads of the testing machine. Any departure from this requirement may introduce bending stresses that are not included in the usual stress computation (load divided by cross-sectional area).

NOTE 3—The effect of this eccentric loading may be illustrated by calculating the bending moment and stress thus added. For a standard 0.500-in. diameter specimen, the stress increase is 1.5 percentage points for each 0.001 in. of eccentricity. This error increases to 2.24 percentage points/0.001 in. for a 0.350-in. diameter specimen and to 3.17 percentage points/0.001 in. for a 0.250-in. diameter specimen.

5.2.2 *Wedge Grips*—Testing machines usually are equipped with wedge grips. These wedge grips generally furnish a satisfactory means of gripping long specimens of ductile metal. If, however, for any reason, one grip of a pair advances farther than the other as the grips tighten, an undesirable bending stress may be introduced. When liners are used behind the wedges, they must be of the same thickness and their faces must be flat and parallel. For best results, the wedges should be supported over their entire length by the heads of the testing machine. This requires that liners of several thicknesses be available to cover the range of specimen thickness. For proper gripping, it is desirable that the entire length of the serrated face of each wedge be in contact with the specimen. Proper alignment of wedge grips and liners is illustrated in Fig. 1. For short specimens it is generally necessary to use machined test specimens and to use a special means of gripping to ensure that the specimens, when under load, shall be as nearly as possible in uniformly distributed pure axial tension (see 5.2.3, 5.2.4, and 5.2.5).

5.2.3 *Grips for Threaded and Shouldered Specimens*—A schematic diagram of a gripping device for threaded-end specimens is shown in Fig. 2, while Fig. 3 shows a device for gripping specimens with shouldered ends. Both of these gripping devices should be attached to the heads of the testing machine through properly lubricated spherical-seated bearings. The distance between spherical bearings should be as large as feasible.

5.2.4 *Grips for Sheet Materials*—The self-adjusting grips shown in Fig. 4 have proved satisfactory for testing sheet materials that cannot be tested satisfactorily in the usual type of wedge grips.

5.2.5 *Grips for Wire*—Grips of either the wedge or snubbing types as shown in Figs. 4 and 5 or flat wedge grips may be used.

5.3 *Dimension-Measuring Devices*—Micrometers and other devices used for measuring linear dimensions shall be accurate to at least one half the smallest unit to which the individual dimension is required to be measured.

6. Test Specimens

6.1 *General*:

6.1.1 Test specimens shall be of the full section of the material whenever practical. Otherwise, machined specimens of rectangular or round cross section shall be used.

6.1.2 Rectangular specimens shall be 0.500 in. wide in accordance with Fig. 6 or Fig. 12 (for tubular products), and shall be of the full thickness of the material when practical. When necessary, 0.250-in. wide subsize specimens as shown in Fig. 6 may be used, but elongation values from such specimens are not applicable to specification requirements.

6.1.2.1 Pin ends as shown in Fig. 7 may be used. In order to avoid buckling in tests of thin and high-strength materials, it may be necessary to use stiffening plates at the grip ends.

6.1.3 Round specimens shall be the standard 0.500-in. diameter specimen in Fig. 8, except when the dimensions of the product make this impossible. In such cases, small-size specimens proportional to the standard specimen shown in Fig. 8 may be used. Unless otherwise specified in the product specification, the selection of round tension specimens shall be as specified in Table 1. Unless permitted by the product specification, the dimensions of the smallest specimen used shall not be less than the following:

	Wrought	Cast
Diameter of reduced section, in.	0.160	0.250
Length of reduced section, in.	¾	1¼
Radius of fillet, in.	⅛	3/16
Diameter of end section, in.	15/64	⅜
Over-all length, in.		
With shouldered ends	1½	2⅜
With threaded ends	2	3
With plain cylindrical ends	3	4

6.1.3.1 The shape of the ends of the specimens outside of the gage length shall be suitable to the material and of a shape to fit the holders or grips of the testing machine so that the loads are applied axially. Figure 9 shows specimens with various types of ends that have given satisfactory results.

6.1.4 Special care is required in the manufacture and testing of smaller specimens because the effects of machining (for example, the amount of end load applied and the amount of heat generated) and testing (for example, eccentricity and gage marking) variables are greater upon them than upon larger specimens. Therefore, the largest practical specimen shall always be used. With some types of materials, notably castings, the result of tests of small specimens may be more variable due to the increasing significance of variations in metallic structure or the character of the surfaces. Low values derived from small specimens should be carefully evaluated in accordance with 8.1 to be certain that the results are valid.

6.1.5 While tensile strengths and yield strengths can properly be compared with results derived from test specimens of various dimensions, elongation values may vary with specimen size and type. Therefore elongation values should be obtained with specimens of the type from which the published tensile properties were established.

6.2 *Type, Direction, and Location in Products:*

6.2.1 *Sheet and Plate:*

6.2.1.1 Rectangular specimens shall be used for thicknesses less than 0.500 in., and round specimens for all others.

6.2.1.2 For thicknesses 0.500 in. through 1.500 in., specimens shall be taken from the center of the thickness; for larger thicknesses, they shall be taken midway from the center to the surface.

6.2.1.3 For nonheat-treatable aluminum alloys, specimens shall be taken parallel to the direction of rolling.

6.2.1.4 For heat-treatable aluminum alloys, specimens shall be taken perpendicular to the direction of rolling (long-transverse). For widths too narrow for long-transverse standard rectangular or 0.500-in. diameter specimens, specimens shall be taken parallel to the direction of rolling.

6.2.1.5 For magnesium alloys, specimens shall be taken parallel to the direction of rolling.

6.2.2 *Wire, Rod, and Bar:*

6.2.2.1 Full-section specimens shall be used when practical. It is permissible to reduce the section slightly throughout the test section in order to ensure fracture within the gage length. Otherwise, round specimens shall be used, except that for rectangles less than 0.500 in. thick rectangular specimens of the full thickness may be used.

6.2.2.2 All specimens shall be longitudinal. The specimens shall be taken from the locations specified in Table 2.

6.2.3 *Shapes:*

6.2.3.1 Round specimens shall be used whenever it is not practical to use full-section specimens, except that for shapes less than 0.500 in. thick, rectangular specimens may be used.

6.2.3.2 All specimens shall be taken in the longitudinal direction from the predominant section of the shape. The specimens shall be taken from a location that most nearly satisfies the intent of Table 2.

6.2.4 *Tube and Pipe*—All specimens shall be longitudinal.

6.2.4.1 For all small tube (Note 4), particularly sizes 1 in. and under in nominal outside diameter, and frequently for larger sizes, except as limited by the testing equipment, it is standard practice to use tension test specimens of full-size tubular sections. Snug-fitting metal plugs shall be inserted far enough into the ends of such tubular specimens to permit the testing machine jaws to grip the specimens properly. The plugs shall not extend into that part of the specimen on which the elongation is measured. Figure 10 shows a suitable form of plug, the location of the plugs in the specimen, and the location of the specimen in the grips of the testing machine.

NOTE 4—The term "tube" is used to indicate tubular products in general, and includes pipe, tube, and tubing.

6.2.4.2 When it is not practical to test full-section specimens, 0.500-in. wide specimens in accordance with Fig. 12 taken as in Fig. 11

shall be used if practical. Otherwise, round specimens shall be taken from the center of wall thicknesses through 1.500 in.; for thicknesses over 1.500 in., they shall be taken midway from center of thickness to surface.

6.2.5 *Die Forgings*—Round specimens shall be used for section thicknesses 0.500 in. and greater. Either subsize round or rectangular specimens may be used for section thicknesses from 0.312 to 0.499 in. Rectangular specimens shall be used for section thicknesses less than 0.312 in. The axis of the specimen shall be substantially parallel to the direction of grain flow, unless specimens in other directions are required. Specimens shall be taken from the center of the predominant or thickest part of the forging from which a coupon can be obtained, from a prolongation of the forging, or from coupons separately forged from the same stock used to produce the forgings.

6.2.6 *Hand Forgings*—Round specimens shall be used. They shall be taken in the long-transverse direction, and when specified, in the longitudinal and short-tranverse directions. A longitudinal specimen shall be taken so that its axis coincides with the longitudinal center line of the forging. A long-transverse or short-transverse specimen shall be taken so that the midpoint of its axis lies on the longitudinal center line of the forging. Each specimen shall be so chosen that the distance from the midpoint of its axis to the end of the forging is at least half the thickness of the forging.

6.3 *Type of Specimen from Castings*:

6.3.1 Test specimens shall be separately cast or, if called for by product specification or customer requirements, machined from the casting itself.

6.3.2 *Cast Test Specimens*—The test section of any separately cast test specimen shall be consistent with Fig. 8.

6.3.3 *Specimens Machined from Castings*:

6.3.3.1 Round specimens in accordance with Fig. 8 shall be used for section thicknesses 0.500 in. and greater.

6.3.3.2 Either small-size round specimens proportional to the standard specimen in Fig. 8 or rectangular specimens in accordance with Fig. 6 may be used for section thicknesses from 0.312 to 0.499 in., except as limited by 6.1.3.

6.3.3.3 Rectangular specimens in accordance with Fig. 6 shall be used for section thicknesses less than 0.312 in.

6.3.3.4 All test specimens must have a machined finish of 63 micro in. RMS (57 micro-in. AA) or smoother.

6.4 *Specimen for Die Castings*:

6.4.1 For testing die castings the test specimen shown in Fig. 13 shall be used unless otherwise provided in the product specifications.

6.5 *Specimens for Powdered Metals*:

6.5.1 For testing powdered metals the test specimens shown in Figs. 14 and 15 shall be used, unless otherwise provided in the product specifications.

7. Procedures

7.1 *Measurement of Dimensions of Test Specimens*:

7.1.1 To determine the cross-sectional area of a tension test specimen, measure the dimensions of the cross section at the center of the reduced section except that for referee testing of specimens under 3/16 in. in their least dimension, measure the dimensions where the least cross-sectional area is found. Measure and record the cross-sectional dimensions of tension test specimens 0.200 in. and over to the nearest 0.001 in.; the cross-sectional dimensions less than 0.200 in. and not less than 0.100 in. to the nearest 0.0005 in.; the cross-sectional dimensions less than 0.100 in. and not less than 0.020 in., to the nearest 0.0001 in.; and when practical, the cross-sectional dimensions less than 0.020 in., to at least the nearest 1 % but in all cases to at least the nearest 0.0001 in.

NOTE 5—Measurements of dimensions presume smooth surface finishes for the specimens. Rough surfaces due to the manufacturing process such as hot rolling, metallic coating, etc., may lead to inaccuracy of the computed areas greater than the measured dimensions would indicate. Therefore, cross-sectional dimensions of tension test specimens with rough surfaces due to processing may be measured and recorded to the nearest 0.001 in.

7.1.2 Determine cross-sectional areas of full-size tension test specimens of nonsymmetrical cross sections by weighing a length not less than 20 times the largest cross-sectional dimension and using the value of density of the material. Determine the weight to the nearest 0.5 % or less.

7.1.3 When using specimens of the type shown in Figure 12 from tubes, the cross-sectional area shall be determined using the following formula:

$$A = \left[\frac{W}{2}\sqrt{R^2 - \frac{W^2}{4}} + R^2 \cdot ARCSIN\frac{W}{D}\right] - \left[\frac{W}{2}\sqrt{r^2 - \frac{W^2}{4}} + r^2 \cdot ARCSIN\frac{W}{d}\right]$$

where:

A = cross-section area,
D = outside diameter,
d = inside diameter,
R = outside radius,
r = inside radius, and
W = width of specimen reduced section.

7.2 *Speed of Testing*:

7.2.1 Speed of testing may be defined (*a*) in terms of free-running crosshead speed (rate of movement of the crosshead of the testing machine when not under load), (*b*) in terms of rate of separation of the two heads of the testing machine during a test, (*c*) in terms of the elapsed time for completing part or all of the test, (*d*) in terms of rate of stressing the specimen, or (*e*) in terms of rate of straining the specimen. For some materials the first of these, which is the least accurate, may be adequate, while for other materials one of the others, listed in increasing order of precision, may be necessary in order to obtain test values within acceptable limits. Suitable limits for speed of testing should be specified for materials for which the differences resulting from the use of different speeds are of such magnitude that the test results are unsatisfactory for determining the acceptability of the material. In such instances, depending upon the material and the use for which it is intended, one or more of the methods described in the following paragraphs is recommended for specifying speed of testing.

7.2.2 *Free-Running Crosshead Speed*—The allowable limits for the rate of movement of the crosshead of the testing machine, when not under load, shall be specified in inches per inch of length of reduced section (or distance between grips for specimens not having reduced sections) per minute. The limits for the crosshead speed may be further qualified by specifying different limits for various types and sizes of specimens. The average crosshead speed can be experimentally determined by using a suitable measuring device and a timing device.

7.2.3 *Rate of Separation of Heads During Tests*—The allowable limits for rate of separation of the heads of the testing machine during a test shall be specified in inches per inch of length of reduced section (or distance between grips for specimens not having reduced sections) per minute. The limits for the rate of separation may be further qualified by specifying different limits for various types and sizes of specimen. Many testing machines are equipped with pacing or indicating devices for the measurement and control of the rate of separation of the heads of the machine during a test, but in the absence of such a device the average rate of separation of the heads can be experimentally determined by using a suitable length-measuring device and a timing device.

7.2.4 *Elapsed Time*—The allowable limits for the elapsed time from the beginning of loading (or from some specified stress) to the instant of fracture, to the maximum load, or to some other stated stress, shall be specified in minutes or seconds. The elapsed time can be determined with a timing device.

7.2.5 *Rate of Stressing*—The allowable limits for rate of stressing shall be specified in pounds per square inch per minute. Many testing machines are equipped with pacing devices for the measurement and control of the rate of stressing, but in the absence of such a device the average rate of stressing can be determined with a timing device by observing the time required to apply a known increment of stress.

7.2.6 *Rate of Straining*—The allowable limits for rate of straining shall be specified in inches per inch per minute. Some testing machines are equipped with pacing or indicating devices for the measurement and control of rate of straining, but in the absence of such a device the average rate of straining can be determined with a timing device by observing the time required to effect a known increment of strain.

7.2.7 Unless otherwise specified, any convenient speed of testing may be used up to one half the specified yield strength, or up to one quarter the specified tensile strength, whichever is smaller. The speed above this point shall be within the limits specified. If different speed limitations are required for use in determining yield strength, tensile strength, and elongation, they should be stated in the product specifications. In the absence of any more specified limitations on speed of testing the following general rules shall apply:

7.2.7.1 The speed of testing shall be such that the loads and strains used in obtaining the test results are accurately indicated.

7.2.7.2 During the conduct of the test to

determine yield strength the rate of stress application shall not exceed 100 000 psi/min. The speed may be increased after removal of the extensometer, but it shall not exceed 0.5 in./in. of gage length (or distance between grips for specimens not having reduced sections) per minute.

7.3 *Rounding*—Round each value of strength to the nearest 0.1 ksi. Round each value of elongation determined in accordance with 7.6.1 to the nearest 0.5 %, unless specified otherwise. Perform rounding according to the rounding method of Recommended Practice E 29.

7.3.1 If elongation is determined in accordance with 7.6.4, round each value in accordance with 7.6.4.4.

7.4 *Yield Strength*—Determine yield strength by the offset method at an offset of 0.2 %. Acceptance or rejection of material may be decided on the basis of Extension-Under-Load Method. For referee testing, the offset method shall be used.

7.4.1 *Offset Method*—To determine the yield strength by the "offset method," it is necessary to secure data (autographic or numerical) from which a stress-strain diagram may be drawn. Then on the stress-strain diagram (Fig. 16) lay off *Om* equal to the specified value of the set, draw *mn* parallel to *OA*, and thus locate *r*, the intersection of *mn* with the stress-strain diagram. (Note 7). In reporting values of yield strength obtained by this method, the specified value of "offset" used should be stated in parentheses after the term yield strength. Thus:

Yield strength (offset = 0.2 %) = 52 000 psi

In using this method a Class B2 extensometer (see Methods E 83) would be sufficiently sensitive for most materials.

NOTE 6—Automatic devices are available that determine offset yield strength without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated to be satisfactory.

NOTE 7—If the load drops before the specified offset is reached, technically the material does not have a yield strength (for that offset), but the stress at the maximum load attained before the specified offset is reached may be reported instead of the yield strength.

7.4.2 *Extension-Under-Load Method*—For tests to determine the acceptance or rejection of material whose stress-strain characteristics are well known from previous tests of similar material in which stress-strain diagrams were plotted, the total strain corresponding to the stress at which the specified offset occurs will be known within satisfactory limits; therefore, in such tests a specified total strain may be used, and the stress on the specimen, when this total strain is reached, is taken to be the value of the yield strength (Fig. 17). The total strain can be obtained satisfactorily by use of a Class B2 extensometer. It is recommended that this approximate method be used only after agreement between the manufacturer and the purchaser, with the understanding that check tests be made for obtaining stress-strain diagrams for use with the offset method to settle any misunderstandings.

7.5 *Tensile Strength*:

7.5.1 Calculate the tensile strength by dividing the maximum load carried by the specimen during a tension test by the original cross-sectional area of the specimen.

7.6 *Elongation*:

7.6.1 Fit ends of the fractured specimen together carefully and measure the distance between the gage marks to the nearest 0.01 in. A percentage scale reading to 0.5 % of the gage length may be used. The elongation is the increase in length of the gage length, expressed as a percentage of the original gage length. In reporting elongation values, give both the percentage increase and the original gage length.

7.6.2 If any part of the fracture takes place outside of the middle half of the gage length or in a punched or scribed mark within the reduced section, the elongation value obtained may not be representative of the material. If the elongation so measured meets the minimum requirements specified, no further testing is required, but the location of fracture shall be noted. If the elongation is less than the minimum requirements, discard the test and test a replacement specimen as allowed in 8.1.1.

7.6.3 In determining extension at fracture (elastic plus plastic extension), autographic or automated methods using extensometers may be employed.

7.6.3.1 In determining percent elongation from extension at fracture, only the plastic extension shall be used. The elastic portion can be estimated graphically or by calculation and subtracted from the total extension at fracture.

7.6.4 When required by the material specification, or when making retests or for referee tests of products other than wire and the specified

elongation is less than 3 % or the elongation measured in the usual manner is less than 4 %, determine the elongation of a round specimen as follows:

7.6.4.1 Mark the original gage length of the specimen and measure to an accuracy of ±0.002 in.

7.6.4.2 Remove any partly torn fragments that might influence the final measurement from the broken ends of the specimen.

7.6.4.3 Match the broken ends together to obtain an integral fit, and apply an end load of approximately 2 ksi. If desired, the load may then be removed carefully, provided the specimen remains intact.

7.6.4.4 Measure the final gage length to at least the nearest 0.002 in., and report the elongation to at least the nearest 0.1 % in 2 in. or 0.2 % in shorter gage lengths.

7.6.5 Measure elongations of ½-in. wide rectangular specimens and of full-section specimens from tube and pipe in 2 in.

7.6.6 Measure elongation of round specimens taken from products 0.125 in. or larger in 4*D* except die casting and wire for electric conductors.

7.6.7 For wire for electric conductors the gage length shall be in 10 in. and elongation shall be measured and reported to the nearest 0.1 %.

7.6.8 Measure elongation of die cast specimens in 8*D* (see Fig. 13).

7.6.9 Measurement of elongation of shapes less than 0.062 in. in thickness and of wire, other than electric conductors, 0.125 in. and less in diameter is not required.

8. Replacement Tests

8.1 A test specimen may be discarded and a replacement specimen selected from the same lot of material when (*1*) the specimen had a poorly machined surface, was not of the proper dimensions, or had its properties changed by poor machining practice; (*2*) the test procedure was incorrect or the test equipment malfunctioned; or (*3*) the fracture was outside the middle half of the gage length, and the elongation was below the specified value.

8.2 In the case of specimens machined from wrought products or castings, discontinuities such as cracks, ruptures, flakes and porosity revealed in the fracture that are considered indicative of inferior or defective material are not reasons for the selection of a replacement test specimen.

8.3 In the case of separately cast test specimens, flaws other than gas porosity, such as cracks or inclusions, are not the cause of rejection of the castings based upon tensile properties, and so the presence of such flaws in the fracture is justification for replacement testing.

9. Retests

9.1 If one or more test specimens fail to conform to the requirements of the product specification, the lot represented by the specimen or specimens shall be subject to rejection except as provided below.

9.2 If a material lot is subject to rejection, retests of that lot will be permitted by:

9.2.1 Testing, for each specimen that failed, at least two additional specimens from an area in the original sample adjacent to the area represented by the failure or failures, or

9.2.2 Testing an additional specimen from the specified location in each of at least two other samples for each sample that failed from the same lot.

9.2.3 In the case of separately cast test specimens, testing two additional cast speciments from the same lot for each specimen that failed.

9.3 If any retest fails, the lot shall be subject to rejection, except that the lot may be resubmitted for testing provided the producer has reworked the lot, as necessary, to correct the deficiencies or has removed the nonconforming material.

10. Precision and Bias

10.1 *Precision*—The degree of agreement within the results obtained in tests made to evaluate a particular property in accordance with the procedures stated in this standard.

10.1.1 Precision is influenced by the homogeneity of specimens. By homogeneity, the material itself, the specimen shape, the gripping methods and measurement methods are meant.

10.1.2 Precision is related to laboratories, the design and condition of the machines and auxiliary equipment and to the skill used by operators.

10.1.3 Results obtained under single operator, single-machine testing can represent the optimum precision.

10.2 *Bias*—The accuracy of the results in tension testing is the degree of agreement between the property defined by the results and an

accepted standard which is the average of a number of observations obtained by operators using the highest skills; using the most suitable machines and equipment and by laboratories having the highest degree of supervision.

10.2.1 Testing machine load accuracy influences accuracy of properties related to force. Specimen geometry, symmetry and alignment influence stress accuracy and strain uniformity. Accuracy of extensometry influences strain magnitude. Gripping devices, qualifications of operators and speed of testing may influence accuracy.

TABLE 1 Guidelines for Selecting Round Tensile Specimens

Specified Material Thickness, in.	Min. Material Section Thickness Length or Width, in.	Specimen Diameter, in.
0.250 through 0.374	1½	0.160
0.375 through 0.499	2½	0.250
0.500 through 0.624	3¼	0.350
0.625 and over	4¾	0.500

10.3 Statistical methods and procedures exist to calculate precision, establish bias and make statistical judgement that numbers defining properties are different only by chance.

NOTE 8—Test results that can be used for statistical evaluation to establish the precision of these methods are not available but are being solicited by ASTM Committee B-7.

NOTE 9—At this time, statements of the accuracy of the results in tension testing should be limited to the documented performance of particular laboratories.

TABLE 2 Location of Axis of Specimens in Rod, Bar, and Shapes

Section Diameter, Thickness or Width, in.	Location of Axis of Specimen with Respect to Thickness (T) and Width (W) of Bar and Shapes or Diameter (D) of Rod		
	Thickness	Width	Diameter
Up through 1.500, incl	$T/2$	$W/2$	$D/2$
Over 1.500	$T/4$	$W/4$	$D/4$

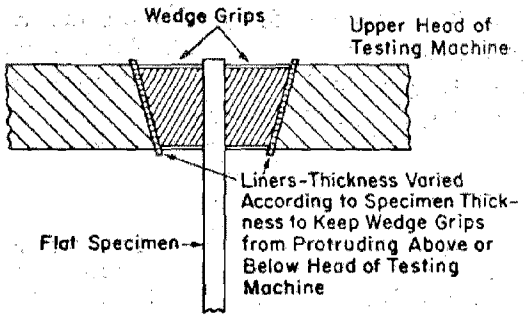


FIG. 1 Wedge Grips with Liners for Flat Specimens

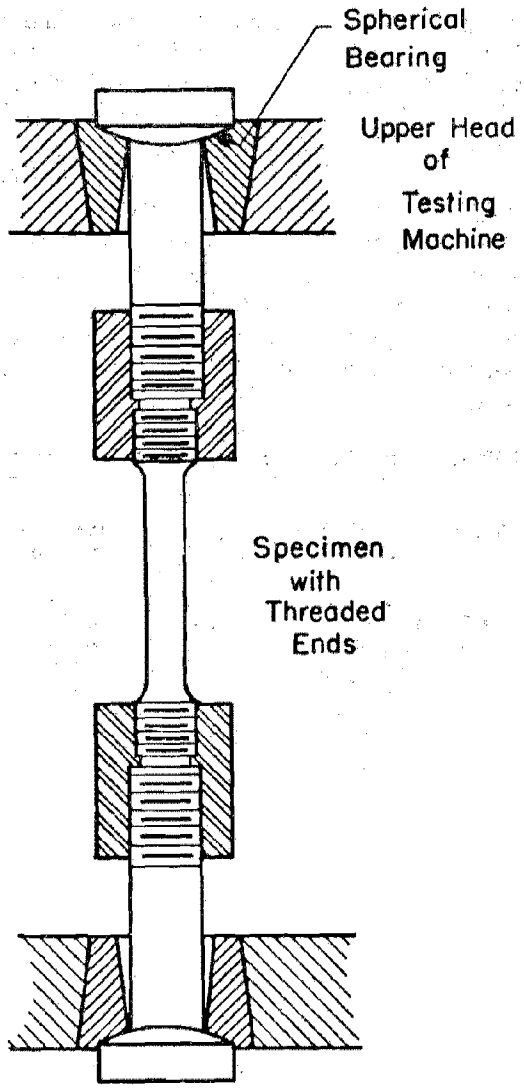


FIG. 2 Gripping Device for Threaded-End Specimens

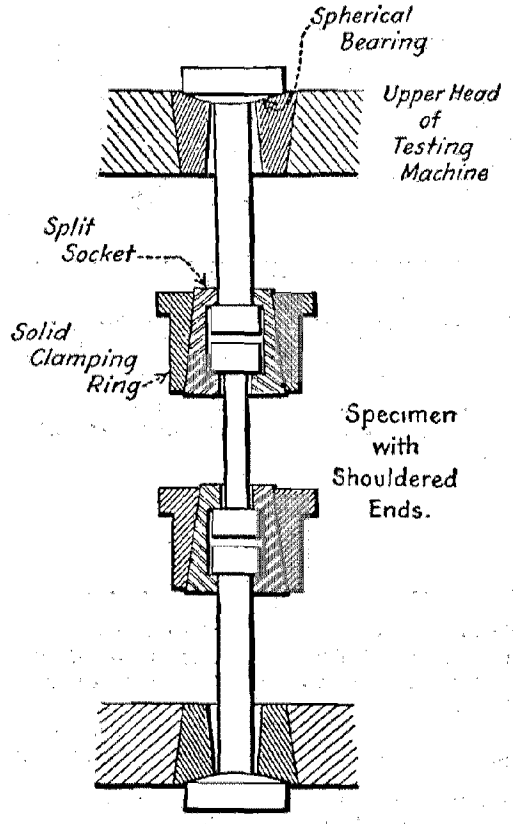


FIG. 3 Gripping Device for Shouldered-End Specimens

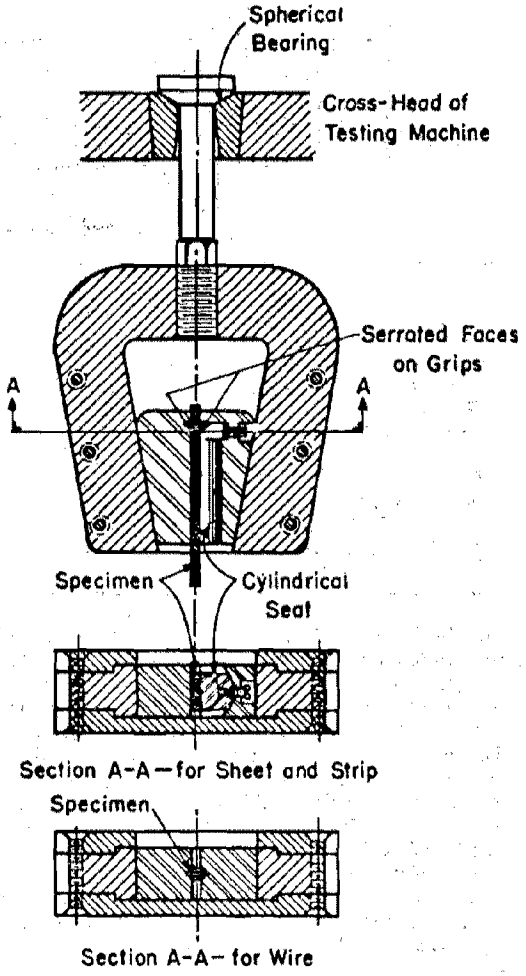


FIG. 4 Gripping Devices for Sheet and Wire Specimens

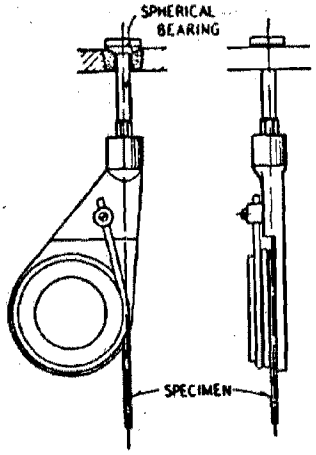
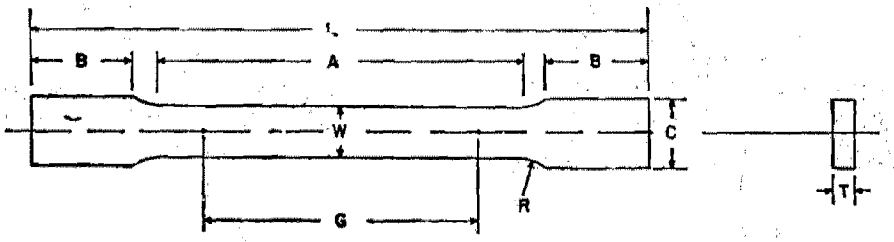


FIG. 5 Snubbing Device for Testing Wire



	Dimensions, in.	
	Standard Specimen Sheet-Type, ½-in. Wide	Subsize Specimen ¼-in. Wide
G— Gage length	2.000 ± 0.005	1.000 ± 0.003
W— Width (Notes 1 and 2)	0.500 ± 0.010	0.250 ± 0.002
T— Thickness (Note 3)	thickness of material	thickness of material
R— Radius of fillet, min	½	¼
L— Over-all length, min (Note 4)	8	4
A— Length of reduced section, min	2¼	1¼
B— Length of grip section, min (Note 5)	2	1¼
C— Width of grip section, approximate (Notes 2 and 6)	¾	⅜

NOTE 1—The ends of the reduced section shall not differ in width by more than 0.002 in. for the 2.00-in. gage length specimen or 0.001 in. for the 1.00-in. gage length specimen. There may be a gradual taper in width from the ends of the reduced section to the center, but the width at each end shall not be more than 1 % greater than the width at the center.

NOTE 2—For each of the specimens, narrower widths (*W* and *C*) may be used when necessary. In such cases the width of the reduced section should be as large as the width of the material being tested permits; however, unless stated specifically, the requirements for elongation in a product specification shall not apply when these narrower specimens are used. If the width of the material is less than *W*, the sides may be parallel throughout the length of the specimen.

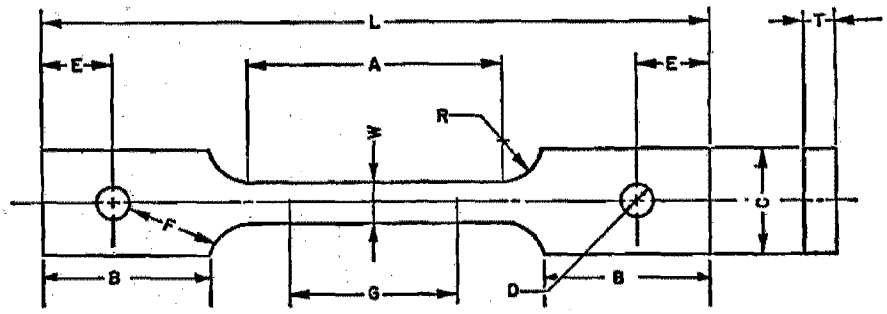
NOTE 3—The dimension *T* is the thickness of the test specimen as stated in the applicable material specifications. Maximum nominal thicknesses of ½-in. and ¼-in. wide specimens shall be ½ in. and ¼ in., respectively.

NOTE 4—To aid in obtaining axial loading during testing of ¼-in. wide specimens, the over-all length should be as large as the material will permit, up to 8 in.

NOTE 5—It is desirable, if possible, to make the length of the grip section large enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips. If the thickness of ½-in. wide specimens is over ⅜ in., longer grips and correspondingly longer grip sections of the specimen may be necessary to prevent failure in the grip section.

NOTE 6—The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.01 and 0.005 in., respectively.

FIG. 6 Rectangular Tension Test Specimens



	Dimensions, in.
G— Gage length	2.000 ± 0.005
W—Width (Note 1)	0.500 ± 0.010
T— Thickness, max (Note 2)	⅝
R— Radius of fillet, min (Note 3)	½
L— Over-all length, min	8
A— Length of reduced section, min	2¼
B— Length of grip section, min	2
C— Width of grip section, approximate	2
D— Diameter of hole for pin, min (Note 4)	½
E— Edge distance from pin, approximate	1½
F— Distance from hole to fillet, min	½

NOTE 1—The ends of the reduced section shall differ in width by not more than 0.002 in. There may be a gradual taper in width from the ends of the reduced section to the center, but the width at each end shall be not more than 1 % greater than the width at the center.

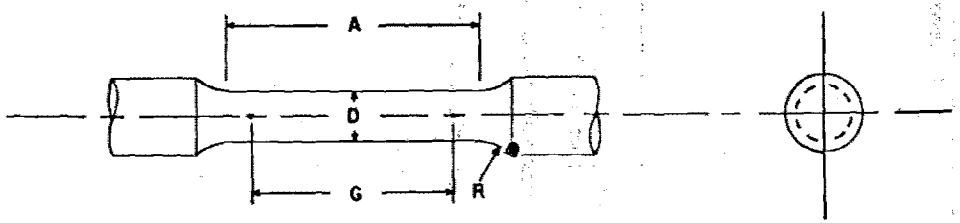
NOTE 2—The dimension *T* is the thickness of the test specimen as stated in the applicable product specifications.

NOTE 3—For some materials, a fillet radius *R* larger than ½ in. may be needed.

NOTE 4—Holes must be on center line of reduced section, within ±0.002 in.

NOTE 5—Variations of dimensions *C*, *D*, *E*, *F*, and *L* may be used that will permit failure within the gage length.

FIG. 7 Pin-Loaded Tension Test Specimen with 2-in. Gage Length



Nominal Diameter	Dimensions, in.			
	Standard Specimen	Small-Size Specimens Proportional to Standard		
	0.500	0.350	0.250	0.160
G—Gage length	2.000 ± 0.005	1.400 ± 0.005	1.000 ± 0.005	0.640 ± 0.005
D—Diameter (Note 1)	0.500 ± 0.010	0.350 ± 0.007	0.250 ± 0.005	0.160 ± 0.003
R—Radius of fillet, min	⅜	¼	9/16	5/32
A—Length of reduced section, min (Note 2)	2¼	1¾	1¼	¾

NOTE 1—The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 1 % larger in diameter than the center (controlling dimension).

NOTE 2—If desired, the length of the reduced section may be increased to accommodate an extensometer of any covenient gage length. Reference marks for the measurement of elongation should, nevertheless, be spaced at the indicated gage length.

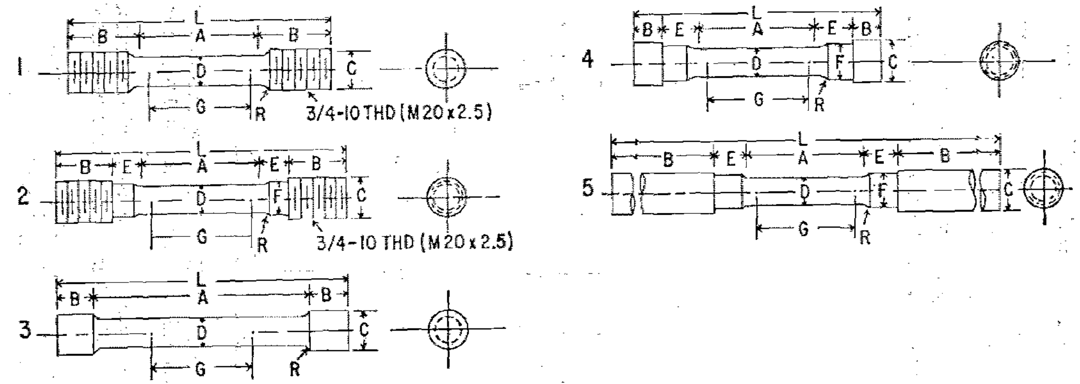
NOTE 3—The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial (see Fig. 9). If the ends are held in wedge grips it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

NOTE 4—On the round specimens in Figs. 8 and 9, the gage lengths are equal to four times the nominal diameter. In some product specifications other specimens may be provided for, but unless the 4-to-1 ratio is maintained within dimensional tolerances, the elongation values may not be comparable with those obtained from the standard test specimen.

NOTE 5—The use of specimens smaller than 0.250-in. diameter shall be restricted to cases when the material to be tested is of insufficient size to obtain larger specimens or when all parties agree to their use for acceptance testing. Smaller specimens require suitable equipment and greater skill in both machining and testing.

NOTE 6—Four sizes of specimens often used have diameters of approximately 0.505, 0.357, 0.252, and 0.160 in., the reason being to permit easy calculations of stress from loads, since the corresponding cross-sectional areas are equal or close to 0.200, 0.100, 0.0500, and 0.0200 $in.^2$, respectively. Thus, when the actual diameters agree with these values, the stresses (or strengths) may be computed using the simple multiplying factors 5, 10, 20, and 50, respectively.

FIG 8 Standard 0.500-in. Round Tension Test Specimen with 2-in. Gage Length and Examples of Small-Size Specimens Proportional to the Standard Specimen

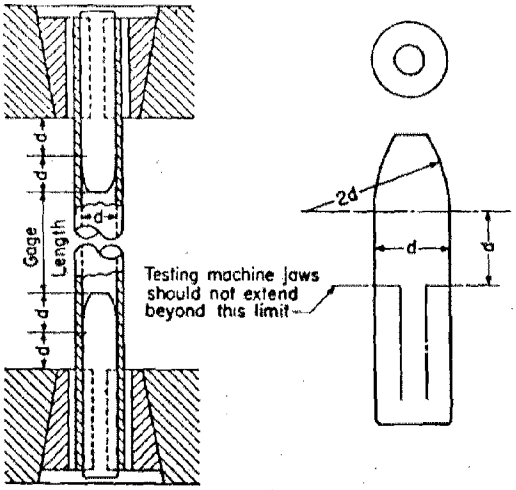


	Dimensions, in.				
	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
G—Gage length	2.000 ± 0.005	2.000 ± 0.005	2.000 ± 0.005	2.000 ± 0.005	2.000 ± 0.005
D—Diameter (Note 1)	0.500 ± 0.010	0.500 ± 0.010	0.500 ± 0.010	0.500 ± 0.010	0.500 ± 0.010
R—Radius of fillet, min	⅜	⅜	$^{1}/_{16}$	⅜	⅜
A—Length of reduced section	2¼, min	2¼, min	4, approximately	2¼, min	2¼, min
L—Over-all length, approximate	5	5½	5½	4¾	9½
B—Length of end section (Note 2)	1⅜, approximately	1, approximately	¾, approximately	½, approximately	3, min
C—Diameter of end section	¾	¾	$^{23}/_{32}$	⅞	¾
E—Length of shoulder and fillet section, approximate	...	⅝	...	¾	⅝
F—Diameter of shoulder	...	⅝	...	⅝	$^{19}/_{32}$

Note 1—The reduced section may have a gradual taper from the ends toward the center with the ends not more than 0.005 in. larger in diameter than the center.

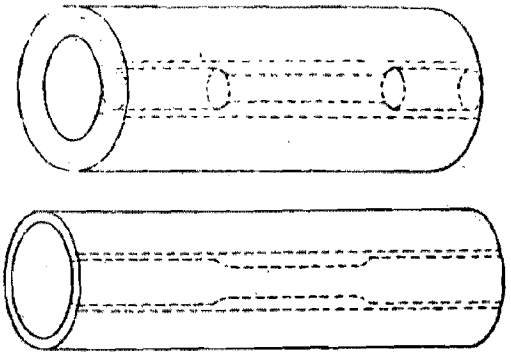
Note 2—On Specimen 5 it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

FIG 9 Various Types of Ends for Standard Round Tension Test Specimen



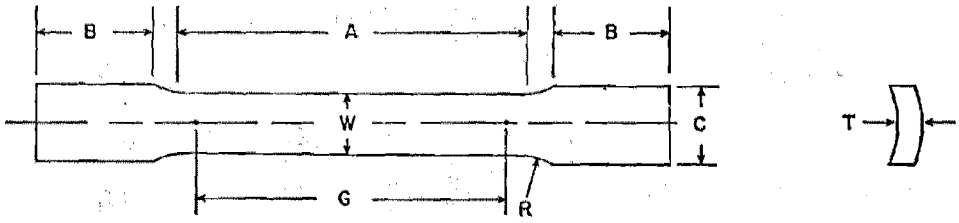
NOTE—The diameter of the plug shall have a slight taper from the line limiting the testing machine jaws to the curved section.

FIG. 10 Metal Plugs for Testing Tubular Specimens, Proper Location of Plugs in Specimen and of Specimen in Heads of Testing Machine



NOTE—The edges of the specimen shall be cut parallel to each other.

FIG. 11 Location from Which Longitudinal Tension Test Specimens Are to Be Cut from Large-Diameter Tube



	Dimensions, in.
W— Width (Note 1)	0.500 ± 0.010
G— Gage length	2.000 ± 0.005
T— Thickness	Note 2
R— Radius of fillet, min	½
A— Length of reduced section, min	2¼
B— Length of grip section, min (Note 3)	3
C— Width of grip section, approximate (Note 4)	1 1/16

NOTE 1—The ends of the reduced section shall not differ in width by more than 0.002 in. There may be a gradual taper in width from the ends of the reduced section to the center, but the width at each end shall not be more than 1 % greater than the width at the center.

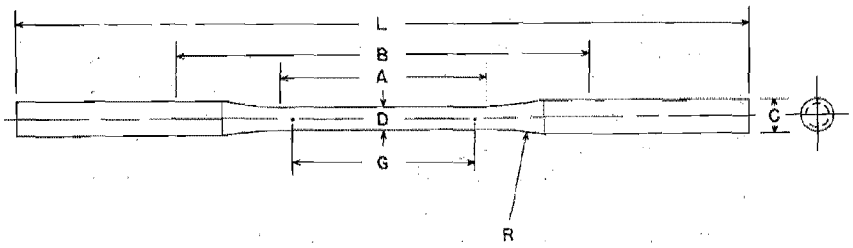
NOTE 2—The dimension *T* is the thickness of the tubular section as provided for in the applicable material specifications.

NOTE 3—It is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

NOTE 4—The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.05 in.

NOTE 5—For circular segment, the cross-sectional area shall be calculated using the formula shown in 7.1.3.

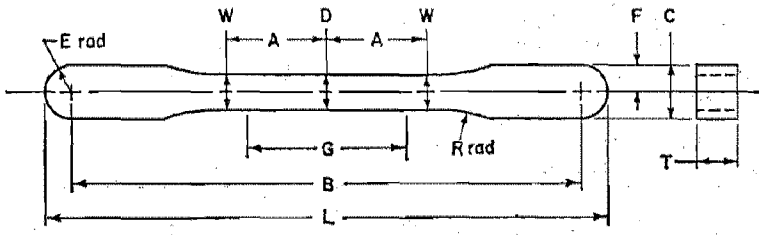
FIG. 12 Longitudinal Tension Test Specimens for Large-Diameter Tubular Products



	Dimensions, in.
G—Gage length	2.000 ± 0.005
D—Diameter (see Note)	0.250 ± 0.005
R—Radius of fillet, min	3
A—Length of reduced section, min	2¼
L—Over-all length, min	9
B—Distance between grips, min	4½
C—Diameter of end section, approximate	⅜

NOTE—The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 0.005 in. larger in diameter than the center.

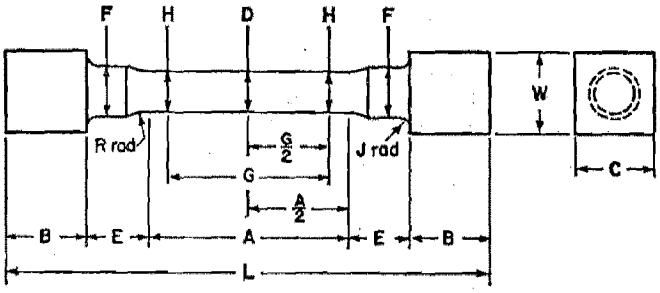
FIG. 13 Standard Tension Test Specimen for Die Castings



Pressing Area = 1.00 in.^{2}
Dimensions Specified except *G*, are Those of the Die.

	Dimensions, in.
G— Gage length	1.000 ± 0.005
D— Width at center	0.225 ± 0.001
W—Width at end of reduced section	0.235 ± 0.001
T— Compact to this thickness	0.200 to 0.250
R— Radius of fillet	1
A— Half-length of reduced section	⅝
B— Grip length	3.187 ± 0.001
L— Over-all length	3.529 ± 0.001
C— Width of grip section	0.343 ± 0.001
F— Half width of grip section	0.1715 ± 0.0010
E— End radius	0.171 ± 0.001

FIG. 14 Standard Tension Test Specimen for Powdered Metal Products—Flat Unmachined Tension Test Specimen



Pressing Area of Unmachined Compact = 1.5 in.^{2}

Machining Recommendations

1. Rough Machine to 5/16 in. dia
2. Finish Turn 0.250 in. dia with Radii and Taper
3. Polish with 00 Emery Cloth
4. Lap with Crocus Cloth

	Dimensions, in.
G— Gage length	1.000 ± 0.005
D— Diameter at center of reduced section	0.250 ± 0.001
H— Diameter at ends of gage length	*D* + 0.001 to 0.002 in.
R— Radius of fillet	¼
A— Length of reduced section	1¼
L— Over-all length (die cavity length)	3
B— Length of end section	½
C— Compact to this end thickness	0.500 ± 0.050
W—Die cavity width	½
E— Length of shoulder and fillet	⅜
F— Diameter of shoulder	5/16
J— End fillet radius, max	1/16

NOTE—The gage length and fillets of the specimen shall be as shown. The ends as shown are designed to provide a total pressing area of 1.00 in.^{2} Other end designs are acceptable, and in some cases are required for high-strength sintered materials. Some suggested alternative end designs include:

1. Longer ends, of the same general shape and configuration as the standard, provide more surface area for gripping.
2. Shallow transverse grooves, or ridges, may be pressed in the ends to be gripped by jaws machined to fit the specimen contour.

FIG. 15 Standard Tension Test Specimen for Powdered Metal Products—Round Machined Tension Test Specimen

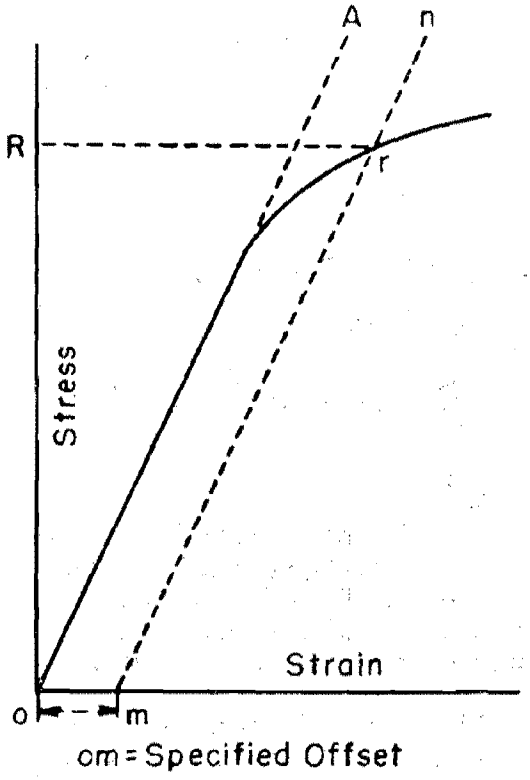


FIG. 16 Stress-Strain Diagram for Determination of Yield Strength by the Offset Method

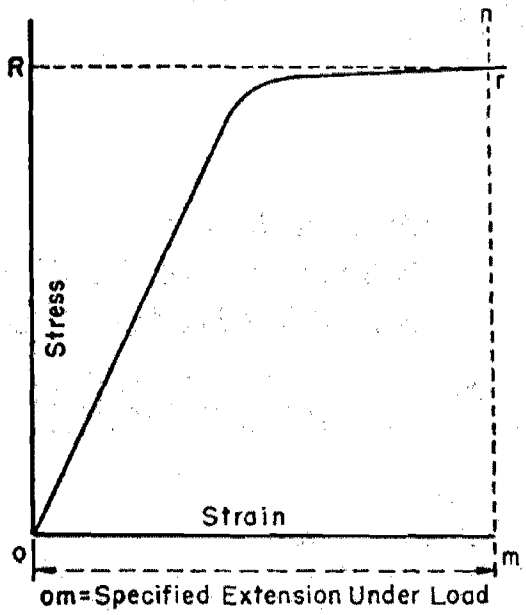


FIG. 17 Stress-Strain Diagram for Determination of Yield Strength by the Extension-Under-Load Method

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By Authority Of
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Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B580: Standard Specification for Anodized Oxide Coatings on Aluminum

CFR Section(s): 49 CFR 171.7

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 580 - 79

An American National Standard

Standard Specification for Anodic Oxide Coatings on Aluminum[1]

This standard is issued under the fixed designation B 580; 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 specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers requirements for electrolytically formed porous oxide coatings on aluminum and aluminum alloy parts where appearance, abrasion resistance, electrical properties, and protection against corrosion are important. Nonporous, barrier layer anodic coatings used for electrical capacitors are not covered. Seven types of coatings as shown in Table 1 are provided. Definitions and typical examples of service conditions are provided in Appendix X1.

NOTE 1—It is recognized that uses exist in which modifications of the coatings covered by this specification may be required. In such cases the particular properties desired by the purchaser should be the subject of agreement between the purchaser and the manufacturer.

2. Referenced Documents

2.1 *ASTM Standards:*

B 110 Test Method for Dielectric Strength of Anodically Coated Aluminum[2]

B 117 Method of Salt Spray (Fog) Testing[3]

B 136 Method for Measurement of Stain Resistance of Anodic Coatings on Aluminum[3]

B 137 Method for Measurement of Weight of Coating on Anodically Coated Aluminum[3]

B 244 Method for Measurement of Thickness of Anodic Coatings on Aluminum and of Other Nonconductive Coatings on Nonmagnetic Basis Metals with Eddy-Current Instruments[3]

B 368 Method for Copper-Accelerated Acetic Acid-Salt Spray (Fog) Testing (CASS Test)[3]

B 457 Method for Measurement of Impedance of Anodic Coatings on Aluminum[3]

B 487 Method for Measurement of Metal and Oxide Coating Thicknesses by Microscopical Examination of a Cross Section[3]

B 538 Method of FACT (Ford Anodized Aluminum Corrosion Test) Testing[3]

B 602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings[3]

D 658 Test Method for Abrasion Resistance of Organic Coatings by the Air Blast Abrasive Test[4]

E 429 Method for Measurement and Calculation of Reflecting Characteristics of Metallic Surfaces Using Integrating Sphere Instruments[5]

E 430 Method for Measurement of Gloss of High-Gloss Surfaces by Goniophotometry[5]

2.2 *Other Standards:*

MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes[6]

MIL-STD-414 Sampling Procedures and Tables for Inspection by Variables for Percent Defective[6]

3. Manufacture

3.1 Defects in the surface of the basis metal, such as scratches, porosity, inclusions, roll and die marks, cold shuts, and cracks, will adversely affect the appearance and performance of applied coatings despite the observance of best anodizing practices. Accordingly, defects in the coating that result from such conditions shall not be cause for rejection.

NOTE 2—To minimize problems of this sort, the specifications covering the basis material or the item to be anodized should contain appropriate limitations on such basis metal conditions.

3.2 The basis metal shall be subjected to such mechanical finishing operations, cleaning, and chemical or electrolytic pretreatments as are necessary to yield anodic coatings with the final quality and appearance specified by the purchaser.

3.3 Except where specifically excluded, anodized parts shall be sealed in water or aqueous chemical solutions of such purity, composition, pH, and temperature, as to impart the properties specified herein.

4. Significant Surfaces

4.1 Significant surfaces are defined as those normally visible (directly or by reflection) which are essential to the appearance of serviceability of the article when assembled in normal position; or those surfaces which can be the source of corrosion products that will deface visible surfaces and interfere with functional surfaces on the assembled article. When necessary, the significant surfaces shall be the subject of agreement between purchaser and manufacturer and shall be indicated on the drawings of the parts, or by the provision of suitably marked samples.

NOTE 3—When significant surfaces are involved on which the specified thickness or density of the coating cannot readily be controlled, such as threads, holes, deep recesses, and similar areas, the purchaser

[1] This specification is under the jurisdiction of ASTM Committee B-8 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.06 on Anodic and Chemical Conversion Coatings on Aluminum and Magnesium Alloys.

Current edition approved May 25, 1979. Published August 1979. Originally published as B 580 – 73. Last previous edition B 580 – 73.

[2] Discontinued, see *1981 Annual Book of ASTM Standards*, Part 9.

[3] *Annual Book of ASTM Standards*, Vol 02.05.

[4] *Annual Book of ASTM Standards*, Vol 06.01.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] Available from the Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120.

and the manufacturer should recognize the necessity for either thicker films on the more accessible surfaces or for special racking.

5. Manner of Specifying Requirements

5.1 *Coating Description*—When ordering articles to be finished in accordance with this specification, the purchaser shall state:

5.1.1 The ASTM designation number,

5.1.2 The coating type and description (see Table 1),

5.1.3 The minimum anodic film thickness,

5.1.4 Special post anodic treatments,

5.1.5 Applicable quality assurance requirements (see Section 6),

5.1.6 Significant surface appearance requirements such as color, texture, or reflectivity, and

5.1.7 The alloy to which the coating is to be applied.

5.2 *Supplementary Coating*—Any supplementary coating that is required in addition to normal or special sealing must either be described in detail along with its requirements or the appropriate specification(s) must be referenced.

6. Quality Assurance

6.1 Anodic oxide coatings can be produced to have many different characteristics. No single coating can be expected to have all of these characteristics. Therefore, the quality assurance requirements for a given coating should be selected to control those properties necessary to the expected end use for the product.

6.2 Anodic coatings supplied under this specification shall meet the minimum requirements for film thickness as stated in Table 1.

TABLE 1 Anodic Coatings Descriptions

NOTE—Hard coatings may vary in thickness from 12 µm to more than 100 µm. If the thickness of Type A is not specified it shall be 50 µm min. Type A coatings will not be sealed unless so specified.

Type	Coating (Industry) Description	Minimum Film Thickness (µm)
A	Engineering Hard Coat	50
B	Architectural Class I	18
C	Architectural Class II	10
D	Automotive—Exterior	8
E	Interior—Moderate Abrasion	5.0
F	Interior—Limited Abrasion	3
G	Chromic Acid	1

6.3 The following ASTM methods are applicable to anodic coatings within the scope of this specification: B 110, B 117, B 136, B 137, B 244, B 368, B 457, B 487, B 538, D 658, E 429, and E 430. The selection of tests to be required and the level of performance against each test, with the exception of minimum film thickness, shall be subject to agreement between purchaser and manufacturer. The Dye Stain Test, as described in Method B 136, shall not be required for Type G coatings or for Types B through F coatings sealed only in dichromate solutions, or for unsealed Type A coatings.

7. Workmanship and Appearance

7.1 *Workmanship*—The anodic coatings shall be continuous, smooth, adherent, uniform in appearance, and shall be free of powdery areas (burns), loose films, stains, discolorations, and discontinuities such as pits, breaks and scratches, or other damage. The size and number of contact marks shall be the minimum consistent with good practice. The location of contact marks shall be in areas of minimum exposure to service environmental conditions when important to the function of the part.

7.2 *Appearance*—If applicable, the color and finish appearance (bright, dull, or satin) shall be a reasonably close approximation to that of a sample consisting of treated pieces agreed upon as the standard range by the manufacturer and the purchaser.

NOTE 4—This range, representing the limits that the manufacturer will supply and that the purchaser will accept, should be established before any work is performed to meet this specification.

8. Sampling

8.1 Test methods are time consuming and often destructive; therefore 100 % inspection is usually impractical. The purchaser should select a suitable sampling plan for the acceptance testing of lots of coated items. In order that the manufacturer may know the quality standard he is expected to meet, the plan selected should be made a part of the purchase contract.

8.2 Information on sampling procedures is given in Method B 602. Standard sampling plans are suggested in Military Standards MIL-STD-105 and MIL-STD-414.

APPENDIX

(Nonmandatory Information)

TABLE X1.1 Definitions of Service Conditions and Examples of Typical Applications and Applicable Coating Types

SC No.	Definition	Typical Applications	Applicable Coating Types
Very Severe (5)	Exposure to atmospheric weathering that can be expected to extend for many years or to prolonged high bearing load wear conditions.	Unmaintained exterior architectural facades, machinery parts, marine	A and B
Severe (4)	Exposure that includes likely damage from denting, scratching, and abrasive wear coupled with corrosive environments.	1-Automotive—exterior, 2-maintained architectural exterior facades, windows	C and D
Moderate (3)	Exposure that is likely to include occasional wetting with coating subject to moderate wear or abrasion.	Lighting reflectors—exterior, athletic equipment, appliances, nameplates, lawn furniture	E
Mild (2)	Exposure indoors in normally dry atmospheres with coating subject to minimum wear or abrasion.	Automotive—interior, houseware items, lighting reflectors—enclosed	F
Crevice Condition (1)	Exposure to humid atmospheres with little or no abrasive condition. Particularly for lap joints.	Spot-welded or riveted assemblies such as aircraft and electronic components.	G

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By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B68: Standard Specification for Seamless Copper Tube, Bright Annealed

CFR Section(s): 46 CFR 56.60-1(b)

Standards Body: American Society for Testing and Materials

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Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 68 – 95

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

This standard is issued under the fixed designation B 68; 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. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by 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, etc, 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 may 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 Values stated in inch-pound units are the standard except for grain size, which is given in SI units.

1.3 This specification is the companion to SI Specification B 68M; therefore, no SI equivalents are presented in this specification.

1.4 The following hazard statement pertains only to the test method described in Sections 20.5 and 21.2.6 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 68M Specification for Seamless Copper Tube, Bright Annealed [Metric][3]

B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing[3]

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

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

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

E 3 Methods of Preparation of Metallographic Specimens[4]

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

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specification[5]

E 53 Methods for Chemical Analysis of Copper[6]

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

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

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

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

E 527 Practice for Numbering Metals and Alloys[8]

3. Ordering Information

3.1 Orders for products should include the following information:

3.1.1 ASTM designation and year of issue (for example, B 68 – 95),

3.1.2 UNS copper number (for example, C10200),

3.1.3 Temper (Section 8),

3.1.4 Dimensions, diameter and wall thickness (Section 16),

3.1.5 How furnished: straight lengths or coils,

3.1.6 Total length, or number of pieces, of each size,

3.1.7 Total weight, each size, and

3.1.8 When product is purchased for agencies of the U.S. Government.

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

3.2.1 Electromagnetic (eddy current) test,

3.2.2 Embrittlement test,

3.2.3 Expansion test,

3.2.4 Flattening test,

3.2.5 Certification, and

3.2.6 Mill test report.

4. General Requirements

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

4.1.1 Terminology, General,

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[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.

Current edition approved Dec. 10, 1995. Published February 1996. Originally published as B 68 – 22T. Last previous edition B 68 – 92a.

[2] Refer to Practice E 527 for explanation of 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 14.02.

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

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

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

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

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 CX10200 shall be 10 ppm max.
[B] Silver counting as copper.

4.1.2 Material and Manufacture,
4.1.3 Workmanship, Finish, and Appearance,
4.1.4 Significance of Numerical Limits,
4.1.5 Inspection,
4.1.6 Rejection and Rehearing,
4.1.7 Certification,
4.1.8 Test Reports,
4.1.9 Packaging and Package Marking, and
4.1.10 Supplementary Requirements.

4.2 In addition, when a section with an identical title to those referenced in 4.1 appears in this specification, such section may contain requirements which supersede those appearing in Specification B 251. In case of conflict, this specification prevails.

5. Terminology

5.1 *Definitions:*

5.1.1 *bright anneal, n*—a thermal treatment carried out in a controlled atmosphere so that surface oxidation is reduced to a minimum and the surface remains relatively bright.

5.2 *Description of Terms Specific to This Standard:*

5.2.1 *unaided eye*—without visual enhancement; however, corrective spectacles necessary to obtain normal vision shall be permitted.

5.2.2 *capable of*—the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.

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 size and wall thickness and shall be bright annealed to meet the specified temper.

7. Chemical Composition

7.1 The material shall conform to the requirements prescribed in Table 1 for the specified copper.

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

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 Practice B 601.

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 when tested in accordance with Test Methods E 8.

10.2 *Elongation:*

10.2.1 The tensile elongation of the tube shall be a minimum 40 % (2 in. gage length) when tested in accordance with Test Methods E 8.

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 B 153.

Outside Diameter, in.	Expansion, %
¾ and under	40
over ¾	30

11.1.1.1 The expanded tube shall show no cracks or ruptures visible to the unaided eye; however, corrective spectacles necessary to obtain normal vision shall be permitted.

11.1.2 A flattening test may be made as an alternate to the expansion test for annealed tube over 4 in. 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 method described in 21.2.6.1 and shall contain no cracks or flaws visible to the unaided eye in the flattened section.

TABLE 2 Average Grain Size Requirements

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

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 B 577. When Copper UNS Nos. C10800 or C12200 are supplied, examination is not required. In case of a dispute, a referee method shall be employed in accordance with Procedure C of Test Methods B 577.

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 B 577. 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 employed in accordance with Procedure C of Test Methods B 577.

14. Nondestructive Testing

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

14.2 *Electromagnetic (Eddy Current) Test:*

14.2.1 When examined in accordance with Practice E 243, tubes which 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 B 251.

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 B 251:

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.

16.2 *Coils, Length Tolerances*—Refer to Tables 2, 3, and 4 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 would not interfere with the intended application are acceptable.

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

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.

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 may 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.

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 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:*

18.2.1 The composite sample shall be prepared from approximate equal weights taken from the sample portions and prepared in accordance with Practice E 255. 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 semi-finished 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 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.

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

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 and 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 Methods E 3.

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 E 8, 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 E 8 may be used 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 B 153.

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	E 53
Phosphorus	E 62

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	E 112
Tensile	E 8
Elongation	E 8
Expansion (Pin Test)	B 153
Microscopical Examination Procedure A	B 577
Hydrogen Embrittlement Procedure B	B 577
Flattening Test	Section 21.3.6
Electromagnetic (Eddy Current) Examination	E 243

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 E 8.

21.2.3 *Microscopical Examination:*

21.2.3.1 Procedure A shall be followed; however, in case of dispute, Procedure C of Test Methods B 577 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 B 577 shall be followed.

21.2.5 *Electromagnetic (Eddy Current) Test*—Each tube up to and including 3⅛ in. in outside diameter shall be subjected to an eddy-current test. Testing shall follow the procedures in Practice E 243. 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 depth or drilled hole standards shall be used.

(A) Notch depth standards, rounded to the nearest 0.001 in. shall be 22 % of the wall thickness. The notch depth tolerance shall be ±0.0005 in.

(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 vary by more than +0.001, −0.000 in. 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

21.2.5.2 Alternatively, at the option of the manufacturer,

using speed insensitive eddy-current units that are equipped so that a fraction of the maximum imbalance signal can be selected, the following percent maximum imbalance signals may be used:

Standard Tube Size, in.	Maximum Percent Imbalance Signal Magnitude
Up to 3/8, incl	0.2
1/2 to 2, incl	0.3
Over 2 to 3, incl	0.4

21.2.5.3 Tubes that do not activate the signalling 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 may, 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

This section identifies the location of selected changes to this specification that have been incorporated since the 1992a issue and the following are some of the changes incorporated in this revision:

(1) Ordering Information: Options available identified.

(2) General Requirements: The applicable sections of Specification B 251 identified.

(3) Number of Tests and Retests: The conditions under which retests is permitted is more definitively stated.

(4) Sampling and Specimen Preparation: Sections added.

(5) Test Methods: Individual test methods are identified; eddy-current test parameters significantly revised.

Designation: B 68M – 95
METRIC

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

This standard is issued under the fixed designation B 68M; 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 bright annealed seamless copper tube suitable for use in refrigeration, oil lines, gasoline lines, etc., 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 may 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 Values stated in SI units are the standard.

1.3 This specification is the companion to inch-pound Specification B 68.

1.4 The following hazard statement pertains only to the test method described in Sections 20.5 and 21.2.6 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 68 Specification for Seamless Copper and Copper Tube, Bright Annealed[3]

B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing[3]

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

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

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

E 3 Test Methods of Preparation of Metallographic Specimens[4]

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

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specification[5]

E 53 Test Methods for Chemical Analysis of Copper[6]

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

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

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

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

E 527 Practice for Numbering Metals and Alloys[8]

3. Ordering Information

3.1 Orders for products should include the following information:

3.1.1 ASTM designation and year of issue (for example, B 68M – 95),

3.1.2 UNS copper number (for example, C10200),

3.1.3 Temper (Section 8),

3.1.4 Dimensions, diameter and wall thickness (Section 13),

3.1.5 How furnished: straight lengths or coils,

3.1.6 Total length, or number of pieces, of each size,

3.1.7 Total weight, each size, and

3.1.8 When product is purchased for agencies of the U.S. Government.

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

3.2.1 Electromagnetic (eddy current) test,

3.2.2 Embrittlement test,

3.2.3 Expansion test,

3.2.4 Flattening test,

3.2.5 Certification, and

3.2.6 Mill test report.

4. General Requirements

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

4.1.1 Terminology, General,

4.1.2 Material and Manufacture,

4.1.3 Workmanship, Finish, and Appearance,

[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.

Current edition approved Dec. 10, 1995. Published February 1996. Originally published as B 68M – 84. Last previous edition B 68M – 92a.

[2] Refer to Practice E 527 for explanation of 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 14.02.

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

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

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

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

4.1.4 Significance of Numerical Limits,
4.1.5 Inspection,
4.1.6 Rejection and Rehearing,
4.1.7 Certification,
4.1.8 Test Reports,
4.1.9 Packaging and Package Marking, and
4.1.10 Supplementary Requirements

4.2 In addition, when a section with an identical title to those referenced in 4.1 appears in this specification, such section may contain requirements which supercede those appearing in Specification B 251M. In case of conflict, this specification prevails.

5. Terminology

5.1 *Definitions:*

5.1.1 *bright anneal*—a thermal treatment carried out in a controlled atmosphere so that surface oxidation is reduced to a minimum and the surface remains relatively bright.

5.2 *Description of Terms Specific to This Standard:*

5.2.1 *unaided eye, n*—without visual enhancement; however, corrective spectacles necessary to obtain normal vision shall be permitted.

5.2.2 *capable of adj.*—the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.

6. Materials and Manufacture

6.1 *Materials:*

6.1.1 The material of manufacture shall be billets, cast 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 process as to produce a homogeneous uniform wrought structure in the finished product. The tube shall be cold drawn to the finished size and wall thickness and shall be bright annealed to meet the specified temper.

7. Chemical Composition

7.1 The material shall conform to the requirements prescribed in Table 1 for the specified copper.

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

8. Temper

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

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

8.1.1 Tempers are defined in Practice B 601.

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 210 MPA when tested in accordance with Test Methods E 8M.

10.2 *Elongation:*

10.2.1 The tensile elongation of the tube shall be a minimum 40 % (50 mm gage length) when tested in accordance with Test Method E 8M.

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 B 153.

Outside Diameter, mm	Expansion, %
.19 and under	40
over 19	30

11.1.1.1 The expanded tube shall show no cracks or ruptures visible to the unaided eye; however, corrective spectacles necessary to obtain normal vision shall be permitted.

11.1.2 A flattening test may be made as an alternate to the expansion test for annealed tube over 4 in. 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 method described in 21.2.6.1 and shall contain no cracks or flaws visible to the unaided eye in the flattened section.

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 B 577. When Copper UNS Nos. C10800 or C12200 are supplied, examination is not

TABLE 1 Chemical Requirements

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 C 10200 shall be 10 ppm max.
[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

required. In case of a dispute, a referee method shall be employed in accordance with Procedure C of Test Methods B 577.

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 B 577. 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 employed in accordance with Procedure C of Test Methods B 577.

14. Nondestructive Testing

14.1 Upon agreement between the manufacturer and the purchaser, each tube up to 79 mm in outside diameter shall be subjected to electromagnetic (eddy current) examination. The tube may be examined in the final drawn or annealed temper, before coiling or in straight lengths prior to final anneal.

14.2 *Electromagnetic (Eddy Current) Test:*

14.2.1 When tested in accordance with Practice E 243, tubes which do not actuate the signaling device of the testing unit shall be considered as conforming to the requirements of the examination.

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 B 251M.

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 B 251M:

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.

16.2 *Coils, Length Tolerances*—Refer to Tables 3, 4, and 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,

TABLE 3 Coil Length Tolerances (Specific Lengths)

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 to only full-length pieces)

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, 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 may be included as follows: up to 10 % of lot weight between 15 mm and one quarter of full length; and up to 40 % between one quarter and full length.

and other defects, but blemishes of a nature that would 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 5000 kg or fraction thereof.

18.1.2 *Portion Size*—Sample portions shall be selected as to represent 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:*

18.2.1 The composite sample shall be prepared from approximately equal weights taken from the sample portions and prepared in accordance with Practice E 255. 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 semi-finished 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 semi-finished product, a sample shall be taken to represent each 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 requested by the manufacturer or supplier, a retest shall be permitted when test results obtained by the purchaser fail to conform with the product specification requirement(s).

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 and 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 Test Methods E 3.

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 E 8M, unless the limitations of the testing machine precludes the use of such specimens.

20.3.2 Test specimens conforming to Specimen No. 1 in Figure 13, Tension Test Specimens for Large-Diameter Tubular Products, of Test Methods E 8M may be used 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 B 153.

20.5 *Flattening Test:*

20.5.1 Test specimens, 102 mm 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	Method
Copper	E 53
Phosphorus	E 62

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
Grain Size	E 112
Tensile	E 8M
Elongation	E 8M
Expansion (Pin Test)	B 153
Microscopical Examination Procedure A	B 577
Hydrogen Embrittlement Procedure B	B 577
Flattening Test	Section 21.3.6
Electromagnetic Examination (Eddy Current)	Practice E 243

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 E 8M.

21.2.3 *Microscopical Examination:*

21.2.3.1 Procedure A shall be followed; however, in case of dispute, Procedure C of Test Methods B 577 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 B 577 shall be followed.

21.2.5 *Electromagnetic (Eddy Current) Test*—Each tube up to and including 79 mm outside diameter, shall be subjected to an eddy-current test. Testing shall follow the procedures in Practice E 243. 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 depth or drilled hole standards shall be used.

(A) Notch depth standards, rounded to the nearest 0.025 mm shall be 22 % of the wall thickness. The notch depth tolerance shall be ±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 vary by more than +0.025 mm, −0.000 mm of the hole diameter specified.

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 so that a fraction of the maximum imbalance signal can be selected, the following percent maximum imbalance signals may be used:

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 signalling 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 may, at the option of the manufacturer, be reexamined or retested to determine whether the discontinuing 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 CHANGE

This section identifies the location of selected changes to this specification that have been incorporated since the 1992a issue and the following are some of the changes incorporated in this revision:

(1) Ordering Information: Options available identified.

(2) General Requirements: The applicable sections of Specification B 251M identified.

(3) Number of Tests and Retests: The conditions under which retests is permitted is more definitively stated.

(4) Sampling and Specimen Preparation: Sections added.

(5) Test Methods: Individual test methods are identified; eddy-current test parameters significantly revised.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B694: Standard Specification for Copper, Copper Alloy, and Copper-Clad Stainless Steel Sheet and Strip for Electrical Cable Shielding

CFR Section(s): 7 CFR 1755.390(i)(5)(v)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 694 – 86

Standard Specification for Copper, Copper Alloy, and Copper-Clad Stainless Steel Sheet and Strip for Electrical Cable Shielding[1]

This standard is issued under the fixed designation B 694; 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 covers selected copper, copper alloy, and copper-clad stainless steel materials, sheet and strip, in various thicknesses, for use as electrostatic or electromagnetic shielding for insulated power, control, instrumentation, and communication cables.

NOTE 1—See Specification B 736, for related standards for aluminum-based shielding materials.

1.2 The materials covered are the following:

Copper or Copper Alloy UNS No.[4]	Type of Material
C11000	copper
C19400	copper-iron alloy
C22000	commercial bronze
C66400	copper-zinc-iron-cobalt alloy
C66410	copper-zinc-iron alloy
C71000	cupro-nickel 20 %
...	copper-clad steel[B]

[4] The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix "C" and a suffix "00." The suffix can be used to accommodate composition variations of the base alloy.

[B] Cladding ratio must be specified, (See 3.1, 7.5, 13.5, and Appendix X3.)

1.3 The values stated in inch-pound units are to be regarded as standard. SI values in parentheses are for information only.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.1.1 *ASTM Standards:*

A 176 Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip[2]

B 152 Specification for Copper Sheet, Strip, Plate, and Rolled Bar[3]

B 193 Test Method for Resistivity of Electrical Conductor Materials[4]

B 248 Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar[3]

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

E 527 Practice for Numbering Metals and Alloys (UNS)[5]

B 736 Specification for Aluminum, Aluminum Alloy and Aluminum-Clad Steel Cable Shielding Stock[6]

3. Definition

3.1 *cladding ratio*—ratio by percent thickness of the component layers, for example, 20/60/20.

4. Ordering Information

4.1 Orders for material under this specification should include the following information:

4.1.1 Quantity: total for each item, pounds (or kilograms),

4.1.2 Name of material: cable shielding (or "cable wrap"),

4.1.3 Form of material: strip,

4.1.4 Type of material: copper, commercial bronze, etc. (see 1.2),

4.1.5 Alloy number when appropriate (see 1.2),

4.1.6 Temper (see Section 8),

4.1.7 Dimensions: thickness and width (see Section 13),

4.1.8 How furnished: coils (rolls), traverse wound on reels or spools, etc.,

4.1.9 Whether the resistivity test is required for any item (Section 12),

4.1.10 Coil dimension: inner or outer coil diameter limitation, or both, if required,

4.1.11 Weight of coils: coil weights or coil size limitations, if required,

4.1.12 Cladding ratio when appropriate (see 7.5),

4.1.13 Certification, if required,

4.1.14 Mill test report, if required,

4.1.15 Specification designation and year of issue, and

4.1.16 Special tests or exceptions, if any.

5. General Requirements

5.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification B 248.

6. Materials and Manufacture

6.1 The material shall be of such quality that it conforms to the properties and characteristics prescribed in this specification.

6.2 Cladding metals as appropriate may be bonded to the specified base metal by any method that will produce a clad

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.01 on Plate, Sheet, and Strip.

Current edition approved Jan. 31, 1986. Published March 1986. Originally published as B 694 – 81. Last previous edition B 694 – 83[ε1].

[2] *Annual Book of ASTM Standards*, Vol 01.03.

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

[4] *Annual Book of ASTM Standards*, Vols 02.01 and 02.03.

[5] *Annual Book of ASTM Standards*, Vols 01.01 and 02.01.

[6] *Annual Book of ASTM Standards*, Vol 02.02.

TABLE 1 Chemical Requirements

Element	Composition, %						Copper Coating of Bimetallic Copper or Copper Alloy UNS No.	
	Copper or Copper Alloy UNS No.							
	C11000	C19400	C22000	C66400	C66410	C71000	C10300	C12200
Copper (incl silver)	99.90 min	97.0 min	89.00–91.0	remainder	remainder	74.0 min	99.95 min[A]	99.9 min
Iron	...	2.1–2.6	0.05 max	1.3–1.7	1.8–2.3	1.0 max	...	...
Lead, max	...	0.03	0.05	0.015	0.015	0.05	...	...
Tin	...	...	...	0.05 max	0.05 max	...	...	...
Zinc	...	0.05–0.20	remainder	11.0–12.0	11.0–12.0	1.0 max	...	...
Nickel (incl cobalt)	...	...	...	...	0.05 max	19.0–23.0	...	...
Manganese	...	...	...	...	0.05 max	1.0 max	...	...
Phosphorus	...	0.015–0.15	...	...	0.02 max	...	0.001–0.005	0.015–0.040
Cobalt	...	...	...	0.30–0.7	...	...	...	...
Silver	...	...	...	...	0.05 max	...	...	...
Silicon	...	...	...	...	0.05 max	...	...	...
Aluminum	...	...	...	...	0.05 max	...	...	...

[A] Copper + silver + phosphorus, min.

material that will conform to this specification.

7. Chemical Composition

7.1 Homogeneous copper-bearing materials shall conform to the chemical requirements prescribed in Table 1.

7.2 Copper cladding shall be, unless otherwise specified, a copper conforming in chemical composition to that covered by Specification B 152, Copper UNS No. C10300 (Table 1). By agreement between manufacturer or supplier and purchaser, Copper UNS No. C12200 (Table 1) may be supplied.

7.3 The specification limits do not preclude the presence of other elements. Limits for unnamed elements may be established by agreement between manufacturer or supplier and purchaser.

7.4 For copper alloys in Table 1, copper may be taken as the difference between all the elements analyzed and 100 %.

7.4.1 *Alloys C19400 and C22000*—When all the elements in Table 1 are analyzed, their sum shall be 99.8 % min.

7.4.2 *Alloys C66400, 664100, and C71000*—When all the elements in Table 1 are analyzed, their sum shall be 99.5 % min.

7.5 Clad cores shall be a stainless steel conforming in chemical composition to any of those covered by Specification A 176. Unless otherwise specified, stainless steel in accordance with UNS No. S43000 (Type 430) shall be supplied.

7.6 Unless otherwise stated (4.1.12), the cladding ratio shall be one of the standard ratios listed in Tables 2 and X2.1, and shall be expressed as XX/XX/XX, copper/stainless steel/copper.

8. Temper

8.1 Materials furnished to this specification shall be annealed or cold-rolled to the temper specified (4.1.6). The standard designations as defined in Practice B 601 are shown. Standard tempers commonly available are listed in Table 2; special or nonstandard tempers are subject to negotiation between manufacturer or supplier and purchaser.

9. Mechanical Properties of Cold-Rolled and Annealed Tempers

9.1 The tension test shall be the standard test for all tempers of cold rolled strip and for annealed Copper UNS No. C11000 and Copper Alloy UNS Nos. C19400, C66400, and C66410 and acceptance or rejection shall depend only on the tensile properties which shall conform to the applicable requirements prescribed in Table 2. Tension test specimens shall be taken so the longitudinal axis of such specimens is parallel to the direction of rolling.

9.2 The mechanical properties of copper-clad steel material in tempers other than fully annealed and with cladding ratios other than listed in Tables 2 and X3.1 shall be as agreed upon between purchaser and supplier.

10. Grain Size Requirements of Annealed Tempers

10.1 Grain size shall be the standard test for annealed strip of Copper Alloy UNS Nos. C22000 and C71000, and acceptance or rejection shall depend only on the grain size. The average grain size of each of two samples of annealed material, as determined on a plane parallel to the surface of the strip, shall be within the limits prescribed in Table 3.

10.2 Although no minimum grain size is prescribed for fully annealed copper-clad steel material, it shall be fully recrystallized in both cladding and core.

11. Rockwell Hardness

11.1 Since Rockwell hardness tests offer a quick and convenient method of checking the conformity of the material to the requirements for tensile strength or grain size, the approximate Rockwell hardness values are given in Table 2 for general information and assistance in testing but shall not be used as a basis for rejection. For copper-clad material, copper should be etched off with suitable reagent prior to testing the steel.

12. Electrical Conductivity

12.1 When specified in the order, the electrical conductivity determined on annealed samples shall have the following value when tested at a temperature of 20°C (68°F):

Material or UNS No.	Electrical Conductivity, min, % IACS
C11000	100.00
C19400	60
C22000	40
C66400	30
C66410	30

TABLE 2 Tensile Strength Requirements and Approximate Hardness Values for Shielding Materials in Commonly Ordered Tempers

Description		Temper Designation		Tensile Strength, ksi[A] (MPa[B])		Approximate Rockwell Hardness[C]		
Copper or Copper Alloy UNS No.	Type of Material	Standard	Former	Min	Max		Other Scales Thicknesses >0.020 in.	Superficial 30T Thicknesses >0.012 in.
			Cold-Rolled Tempers:					
C11000	Copper	H00	eighth hard	32 (220)	40 (275)	F	54–82	up to 49
		H01	quarter hard	34 (235)	42 (290)	F	60–84	18–51
		H02	half hard	37 (255)	46 (315)	F	77–89	43–57
			Annealed Tempers:					
		O61	annealed	...	34 (235)		...	...
			Annealed Tempers:					
C19400	Copper-iron alloy	O61	annealed[C]	45 (310)	55 (380)		...	...
		O50	light annealed[C]	50 (345)	60 (415)		...	...
		H02	half hard	53 (365)	63 (435)	B	49–69	52–63
			Cold-Rolled Tempers:					
C22000	Commercial bronze	H01	quarter hard	40 (275)	50 (345)	B	27–52	38–53
		H02	half hard	47 (325)	57 (395)	B	50–63	52–61
			Annealed Tempers:					
		O81	quarter hard	39 (270)	46 (315)		...	...
			Annealed Temper:					
C66400	Copper-zinc-iron-cobalt alloy	O60	soft[C]	53 (365)	60 (415)		...	...
C66410	Copper-zinc-iron alloy	O60	soft[C]	53 (365)	60 (415)		...	...
			Cold-Rolled Tempers:					
C71000	Cupro-nickel 20 %	H01	quarter hard	47 (325)	63 (435)	B	45–72	46–65
		H02	half hard	56 (385)	70 (485)	B	64–78	59–69
			Annealed Tempers:					
		OS035	0.035-mm grain size	52 (355)		B	18–35	28–40
		OS015	0.015-mm grain size	53 (365)		B	35–88	40–56
Copper-Clad Steel								
Cladding Ratio	Total Thickness in. (mm)							
			Annealed Tempers					
20/60/20	0.004 (0.10)	O61	annealed[C]	51 (350)		15T	89 max	...
16/68/16	0.005 (0.13)	O61	annealed[C]	55 (380)	68 (470)	15T	89 max	...
33.3/33.3/33.3	0.006 (0.15)	O61	annealed[C]	44 (305)		15T	89 max	...

[A] ksi = 1000 psi.
[B] See Appendix X4.
[C] There is no grain size requirement but all annealed metal shall be fully recrystallized.
[D] Rockwell values normally apply as follows: The B and F scales apply to metal 0.020 to 0.036 in. (0.5 to 0.91 mm) in thickness. The Superficial 30-T scale applies to metal 0.012 to 0.028 in. (0.30 to 0.71 mm) in thickness.

Material or UNS No.	Electrical Conductivity, min, % IACS
C71000 Copper-clad steel	6[A]

[A] Conductivity for preferred thicknesses and cladding ratios shall be as shown in Table X3.1. Conductivity for other thicknesses or for other cladding ratios shall be as agreed upon between purchaser and supplier.

12.2 The electrical resistivity of the material shall be determined in accordance with Test Method B 193; the conductivity shall be calculated in accordance with Explanatory Notes 3 and 4 of Test Method B 193.

13. Dimensions and Permissible Variations

13.1 *General*—For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the specified limiting values for any dimension may be cause for rejection.

13.2 *Thickness*—The standard method of specifying thickness shall be in decimal fractions of an inch. For material 0.021 in. (0.53 mm) and under in thickness, it is recommended that the nominal thicknesses be stated not closer than the nearest half-thousandth. (For example, specify 0.006 or 0.0065 in. (0.15 or 0.165 mm), but not 0.0063 in. (0.160 mm).) A list of preferred thicknesses is shown in Appendix X1. The thickness tolerance shall be those shown in Tables 4(*a*) and 4(*b*).

TABLE 3 Grain Size Requirements for Annealed Material

Copper Alloy UNS No.	Temper Designation		Average Grain Size, mm		
	Standard	Former	Nominal	Min	Max
C22000	OS010		0.010	[A]	0.020
C71000	OS015	annealed	0.015	[A]	0.025

[A] Although no minimum grain size is required, this material must be fully recrystallized.

13.3 *Width*—The width tolerances shall be those required by Specification B 248, Paragraph 5.3, unless otherwise stated in the purchase order.

13.4 *Straightness*—The straightness tolerances shall be those required by Specification B 248, paragraph 5.5, unless otherwise stated in the purchase order.

13.5 *Cladding Ratio*—Cladding ratios shall be within ±10 % of nominal; test method shall be metallurgical

TABLE 4(a) Thickness Tolerances

Material	Thickness, in. (mm)	Tolerance, plus and minus in. (mm)	
		12 in. (305 mm) and under in Width	Over 12 in. (305 mm) and up to 24 in. (610 mm) in width
Copper and copper alloys	0.004 (0.102) and under	0.0003 (0.0076)	0.0006 (0.015)
	Over 0.004 to 0.005 (0.127), incl	0.0004 (0.010)	0.0008 (0.020)
	Over 0.005 to 0.009 (0.229), incl	0.0005 (0.013)	0.001 (0.025)
	Over 0.009 to 0.013 (0.330), incl	0.0008 (0.020)	0.0015 (0.038)
Copper-clad steel	0.004 (0.102) and under		
	Over 0.004 to 0.006 (0.152), incl	0.0005 (0.013)	
	Over 0.006 to 0.009 (0.229), incl	0.0006 (0.015)	

microsection of at least three samples per lot. See Appendix X3 for preferred cladding ratios.

14. Workmanship, Finish, and Appearance

14.1 All material shall be uniform in quality and condition, sound and free of internal and external defects of a nature that interferes with normal fabrication or the performance of the cable shielding. It shall be well-cleaned and free of dirt. A superficial film of residual light lubricant is permissible, unless otherwise specified.

14.2 Copper-clad material shall be free of defects including unbond or delamination of a nature that interferes with normal commercial operations.

TABLE 4(b) Width Tolerances for Slit Metal and Slit Metal with Rolled Edges

(Applicable to all materials listed in 1.2)

Width, in. (mm)	Width Tolerances,[A] plus and minus	
	For All Thicknesses	
	in.	mm
2 (50.8) and under	0.005	0.13
Over 2 to 12 (50.8 to 305), incl	0.008	0.20
Over 12 to 24 (305 to 610), incl	0.015	0.38

[A] If tolerances are specified as all plus or all minus, double the values given.

APPENDIXES

(Nonmandatory Information)

X1. EXPLANATORY NOTE—CABLE SHIELDING

X1.1 Cable shielding or "cable wrap" is normally used by manufacturers of electrical insulated wire and cable in strips of various widths. The material is wrapped around an insulated wire or group of wires, and may be applied over an intervening layer of wrapping material or over a jacket. The material may be applied in various configurations depending upon the requirements of the finished cable:

X1.1.1 *Helical wrap*—overlapped, butted, or gapped.

X1.1.2 *Longitudinal application*—corrugated or smooth, overlapped, butted, gapped, or welded/soldered.

X1.2 The selection of the particular material and of the thickness of the material to be used is dependent largely upon the specification requirements for the finished wire or cable. Military and Federal Specifications, Rural Electrification Administration (REA) specifications, ICEA (Insulated Cable Engineers Association) specifications among others, typically apply.

X1.3 Electrical conductivity of the material is an important characteristic considered in the selection process, and is affected by the material, its thickness, and the method of application. Corrosion resistance is important for various environments. Physical strength requirements may include such features as resistance to tensile stress, resistance to bending stress (including repeated bending), resistance to gopher attack, etc.

X2. PREFERRED THICKNESSES

X2.1 It is recommended that wherever possible, material purchased to this specification be ordered in a thickness as listed in Table X2.1.

TABLE X2.1 Preferred Thickness, Nominal

Material or UNS No.	Thickness, in. (mm)
C11000	0.005 (0.13) 0.010 (0.25)
C19400	0.006 (0.15) 0.007 (0.18)
C22000	0.005 (0.13) 0.007 (0.18) 0.010 (0.25)
C66400	0.0055 (0.14)
C66410	0.0055 (0.14)
C71000	0.005 (0.13)
Copper-clad steel	0.004 (0.10)[A] 0.005 (0.13)[A] 0.006 (0.15)[A]

[A] Total thickness of strip. See Table X3.1 for preferred cladding ratio.

X3. PREFERRED CLADDING RATIOS FOR COPPER-CLAD STEEL

X3.1 It is recommended that wherever possible, material purchased to this specification be ordered in thicknesses and cladding ratios as listed in Table X3.1. Conductivity for these recommended materials is indicated.

TABLE X3.1 Preferred Cladding Ratios—Copper-Clad Steel

Nominal Total Thickness of Strip		Cladding Ratio, Cu/ss/Cu	Nominal Thickness, in. (mm)			Conductivity, % IACS	
in.	mm		Copper	Steel	Copper	nominal	min
0.004	0.10	20/60/20	0.0008 (0.02)	0.0024 (0.06)	0.0008 (0.02)	32	30
0.005	0.13	16/68/16	0.0008 (0.02)	0.0034 (0.09)	0.0008 (0.02)	30	28
0.006	0.15	33.3/33.3/33.3	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	61	60

X4. METRIC EQUIVALENTS

X4.1 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.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B75: Standard Specification for Seamless Copper Tube

CFR Section(s): 46 CFR 56.60-1(b)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 75 – 97

Standard Specification for Seamless Copper Tube[1]

This standard is issued under the fixed designation B 75; 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 specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope*

1.1 This specification[2] establishes the requirements for seamless round, rectangular, and square copper tube suitable for general engineering applications.

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.	Type of Copper
C10100	Oxygen-free electronic
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 The values stated in inch-pound units are the standard except for grain size values which are given in SI units.

1.3 This specification is the companion to SI Specification B 75M; therefore no SI equivalents are presented in this specification.

1.4 The following hazard statement pertains only to the test method described in Sections 20.5.2.1, 21.2.9, and 21.2.10 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 75M Specification for Seamless Copper Tube (SI)[3]

B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing[3]

B 170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes[3]

B 193 Test Method for Resistivity of Electrical Conductor Materials[4]

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 Designations for Copper and Copper Alloys—Wrought and Cast[3]

E 3 Test Methods of Preparation of Metallographic Specimens[5]

E 8 Test Methods for Tension Testing of Metallic Materials[5]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[5]

E 53 Test 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[5]

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]

E 527 Practice for Numbering Metals and Alloys (UNS)[8]

3. Ordering Information

3.1 Orders for product shall include the following information:

3.1.1 ASTM designation and year of issue (for example, B 75 – 95),

3.1.2 Copper UNS No. (for example, C10100),

3.1.3 Temper (Section 8),

3.1.4 Dimensions; diameter or distance between parallel surfaces, and wall thickness (Section 17),

3.1.5 How furnished; coils or straight lengths,

3.1.6 Number of pieces or footage; each size and type,

3.1.7 Total weight,

3.1.8 When product is purchased for ASME Boiler and Pressure Vessel Code application, and

3.1.9 When product is purchased for agencies of the U.S. Government.

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

3.2.1 Electrical mass resistivity test,

3.2.2 Hydrogen embrittlement test,

3.2.3 Hydrostatic test,

3.2.4 Pneumatic test,

[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.

Current edition approved Feb. 10, 1997. Published October 1997. Originally published as B 75 – 28T. Last previous edition B 75 – 95a.

[2] For *ASME Boiler and Pressure Vessel Code* applications refer to related Specification SB-75 in Section II of that Code.

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

[4] *Annual Book of ASTM Standards*, Vol 02.03.

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

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

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

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

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

TABLE 1 Chemical Requirements

Element	Composition, %						
	Copper UNS No.						
	C10100[A]	C10200[B]	C10300	C10800	C12000	C12200	C14200
Copper[C], min	99.99	99.95	...	...	99.90	99.9	99.40
Copper[C] + phosphorus, min	...	...	99.95	99.95	...	...	...
Phosphorus	...	...	0.001–0.005	0.005–0.012	0.004–0.012	0.015–0.040	0.015–0.040
Arsenic	...	...	...	...	...	...	0.15–0.50

[A] Refer to Table 1, Chemical Requirements, Grade 1, of Specification B 170 for impurity limits for Copper UNS No. C10100.
[B] Refer to Table 1, Chemical Requirements, Grade 2, of Specification B 170 for impurity limits for Copper UNS No. C10200.
[C] Copper (including silver).

3.2.5 Certification, and
3.2.6 Test report.

4. General Requirements

4.1 The following sections of Specification B 251 are a part of this specification.
4.1.1 Terminology, General,
4.1.2 Material and Manufacture,
4.1.3 Workmanship, Finish, and Appearance,
4.1.4 Significance of Numerical Limits,
4.1.5 Inspection,
4.1.6 Rejection and Rehearing,
4.1.7 Certification,
4.1.8 Mill Test Reports,
4.1.9 Packaging and Package Marking, and
4.1.10 Supplementary Requirements.

4.2 In addition, when a section with an identical title to those referenced in 4.1 appears in this specification, and is in conflict with the section appearing in Specification B 251, the section in this specification shall prevail.

5. Terminology, Specific

5.1 *Definitions of Terms Specific to This Specification:*

5.1.1 *capable of*—the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.

5.1.2 *unaided eye*—without visual enhancement; however, corrective spectacles necessary to obtain normal vision shall be permitted.

6. Material and Manufacture

6.1 *Material*—The material of manufacture shall be billets, bars, or tube of Copper UNS[9] No. C10100, 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*—The tube shall be manufactured by such hot- and cold-working processes as to produce a homogeneous, uniform wrought structure in the finished product. It shall be cold drawn to the finished size and wall thickness. When cold-drawn temper is required, the final drawing operation shall be such as to meet the specified temper. When annealed temper is required, the tube shall be annealed subsequent to the final cold draw.

[9] Refer to Practice E 527 for explanation of unified numbering system (UNS).

7. Chemical Composition

7.1 The material shall conform to the requirements in Table 1 for the specified Copper UNS No. designation.

7.1.1 These specification limits do not preclude the presence of other elements. Limits are permitted to be established and analysis required for unnamed elements by agreement between the manufacturer or supplier and the purchaser.

8. Temper

8.1 The requirements and size availability of tube in the cold-drawn tempers H55, H58, and H80, as defined in Practice B 601, are specified in Table 2.

8.1.1 Rectangular, including square, tube shall normally be supplied only in H58 temper; however, tube in H55 or H80 temper is permitted to be supplied as agreed upon between the manufacturer and the purchaser.

8.1.1.1 For any combination of diameter and wall thickness not listed under H80 temper, the requirements specified for H58 temper shall apply.

8.2 The requirements and size availability of tube in the annealed tempers O50 and O60, as defined in Practice B 601, are specified in Table 2.

NOTE 1—The purchaser shall confer with the manufacturer or supplier for the availability of product in a specific temper.

NOTE 2—Refer to Appendix X1 for recommended applications based on temper.

9. Grain Size Requirements

9.1 Tube in the annealed temper shall conform to the grain size specified in Table 2.

10. Physical Property Requirements

10.1 *Electrical Resistivity*—When specified in the contract or purchase order, tube ordered for electrical conductor application produced from Copper UNS No. C10100, C10200, C10300, or C12000 shall have an electrical mass resistivity, $\Omega \cdot g/m^2$, not to exceed the following limit for the specified copper and temper when tested in accordance with Test Method B 193:

Temper	Copper UNS No.			
	C10100	C10200	C10300	C12000
O60, O50	0.15176	0.15328	0.15614	0.17031
H55, H58, H80	0.15614	0.15737	0.15940	0.17418

NOTE 3—Refer to Appendix X2 for the International Annealed Copper Standard (IACS) electrical conductivity equivalents.

TABLE 2 Mechanical Property Requirements of Drawn-Temper and Annealed-Temper Tube

Temper Designation		Outside Diameter, or Major Distance Between Outside Parallel Surfaces, in.	Wall Thickness, in.	Rockwell Hardness		Average Grain Size, mm	Tensile Strength, ksi[B]	Yield Strength,[A] min., ksi[B]
Standard	Former			Scale	Hardness			
H55	Light-drawn[C]	all	all	30T[D]	30 to 60		36–47	30
H58	Drawn (general purpose)	all	all	30T[D]	30 min		36 min	30
H80	Hard-drawn[C]	up to 4	0.020 to 0.250, incl	30T[D]	55 min		45 min	40
O60	Soft anneal	all	0.015 to 0.035	15T[E]	60 max	0.040 min	30 min	9[F]
			0.035 and over	F[E]	50 max	0.040 min	30 min	9[F]
O50	Light anneal	all	0.015 to 0.035	15T[E]	65 max	0.040 max	30 min	9[F]
			0.035 and over	F[E]	55 max	0.040 max	30 min	9[F]

[A] Yield strength to be determined at 0.5 % extension under load.
[B] ksi = 1000 psi.
[C] Light-drawn and hard-drawn tempers are normally available in round tubes only.
[D] Rockwell hardness values shall apply only to tubes having a wall thickness of 0.020 in. or over, to round tubes having an inside diameter of 5/16 in. or over, and to rectangular including square tubes having an inside major distance between parallel surfaces of 3/16 in. or over. Rockwell hardness tests shall be made on the inside surface of the tube. When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values are permitted to be specified to agreement between purchaser and supplier.
[E] Rockwell hardness values shall apply only to tubes having a wall thickness of 0.015 in. or over, to round tubes having an inside diameter of 5/16 in. or over, and to rectangular including square tubes having an inside major distance between parallel surfaces of 3/16 in. or over. For all other tube no Rockwell values shall apply. Rockwell hardness tests shall be made on the inside surface of the tube. When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values are permitted to be specified subject to agreement between purchaser and supplier.
[F] Light straightening operation is permitted.

11. Mechanical Property Requirements

11.1 *Tensile and Yield Strength:*

11.1.1 The tube shall conform to the requirements of Table 2 for the specified temper and wall thickness.

11.1.2 For any combination of diameter and wall thickness not listed under H80, the requirements for H58 shall apply.

11.2 *Rockwell Hardness:*

11.2.1 The tube shall conform to the requirements of Table 2 for the specified temper and wall thickness.

11.2.1.1 The Rockwell Hardness values for tube in the H55, H58, and H80 temper shall apply only to the following:

(a) Tubes having a wall thickness of 0.020 in. and over,

(b) Round tubes having an inside diameter of 5/16 in. and over,

(c) Rectangular and square tubes having major distances between parallel surfaces of 3/16 in. and over.

11.2.1.2 The Rockwell Hardness values for tube in the O60 and O50 temper shall apply only to the following:

(a) Tubes having a wall thickness of 0.015 in. and over;

(b) Round tubes having an inside diameter of 5/16 in. and over;

(c) Rectangular and square tubes having inside major distances between parallel surfaces of 3/16 in. and over.

11.3 *Straightening*—Light straightening is permitted for tube in the O60 and O50 temper.

12. Performance Requirements

12.1 *Expansion Test for Round Tube*—When specified in the contract or purchase order, annealed tubes shall be capable of withstanding an expansion of the outside diameter of 40 % for tube 3/4 in. and under and 30 % for tube over 3/4 in. The tube shall show no cracking or rupture visible to the unaided eye.

13. Microscopical Examination

13.1 Tubes furnished in Copper UNS No. C10100, C10200, C10300, and C12000 shall be essentially free of cuprous oxide as determined by Procedure A of Test Methods B 577.

14. Hydrogen Embrittlement

14.1 When specified in the contract or purchase order, tubes produced in all designated copper material shall be capable of conforming to the requirements of Procedure B of Test Methods B 577.

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 B 251.

16. Nondestructive Test

16.1 The tubes shall be tested in the drawn tempers or as drawn prior to the final-annealed temper unless otherwise agreed upon between the manufacturer and the purchaser.

16.2 *Electromagnetic (Eddy Current) Test:*

16.2.1 Each tube up to and including 3 1/8 in. in outside diameter shall be subjected to test.

16.2.2 When tested in accordance with Practice E 243, tubes which do not actuate the signaling device of the testing unit shall be considered as conforming to the requirements of the test.

TABLE 3 Coil Length Tolerances (Specific Lengths)

Outside Diameter or Major Distance Between Parallel Surfaces, in.	Tolerances, in., All Plus, for Nominal Lengths, ft	
	Up to 50, incl	Over 50 to 100, incl
Up to 2, incl	12	24

16.3 *Hydrostatic Pressure Test*—When specified in the contract or purchase order, each tube shall be capable of withstanding an internal hydrostatic pressure sufficient to produce a fiber stress of 6000 psi without leakage. The tube need not be subjected to a pressure gage reading over 1000 psi unless specifically stipulated in the contract or purchase order.

16.4 *Pneumatic Pressure Test*—When specified in the contract or purchase order, each tube shall be capable of withstanding an internal air pressure of 60 psi, minimum, for 5 s without leakage.

17. Dimensions, Mass, and Permissible Variations

17.1 The dimensions and tolerances for product furnished to this specification shall be as specified in the following tables and related sections of the current edition of Specification B 251:

17.1.1 *Wall Thickness Tolerances*—Refer to Tables 1 and 2.

17.1.2 *Tolerances for Diameter or Distance Between Parallel Surfaces*—Refer to Tables 3 and 4.

17.1.3 *Length Tolerances*—Refer to Tables 5 and 6.

17.1.4 *Straightness Tolerance*—Refer to Table 7.

17.1.5 *Corner Radius for Rectangular Including Square Tube*—Refer to Table 8.

17.1.6 *Roundness, Squareness of Cut and Twist Tolerances for Rectangular and Square Tubes*—Refer to titled sections.

17.2 *Length Tolerances for Tube in Coils*—Refer to Tables 3, 4, and 5 of Specification B 75.

18. Sampling

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

18.1.1 *Lot Size*—An inspection lot shall be 10 000 lb or fraction thereof,

18.1.2 *Portion Size*—Sample pieces shall be selected to be represented of the lot as follows:

Number of Pieces in Lot	Number of Portions to Be Taken[A]
1 to 50	1
51 to 200	2
201 to 1500	3

[A] Each test portion shall be taken from a separate tube.

18.2 *Chemical Composition:*

18.2.1 The composite sample shall be taken in approximate equal weights from each portion piece selected in 18.1.2 and in accordance with Practice E 255. The minimum weight of the composite shall be 150 g.

18.2.2 The manufacturer shall have the option of sampling at the time the castings are poured or taken from the semifinished product. The number of samples taken during the course of manufacture shall be as follows:

18.2.2.1 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.

18.2.2.2 When samples are taken from the semifinished 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.

18.2.2.3 When composition is determined during the course of manufacture, sampling and analyses of the finished product is not required.

18.3 *Other Tests*—Specimens for all other tests shall be taken from two of the sample portions taken in 18.1.2. In the event only one sample portion is taken, all specimens shall be taken from the portion selected.

19. Number of Tests and Retests

19.1 *Tests:*

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

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

Tube Outside Diameter or Major Distance Between Parallel Surfaces, in.	Tolerances, %, for Nominal Lengths, ft	
	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.

TABLE 5 Coil Schedule of Mill Lengths with Ends

Tube Outside Diameter or Major Distance Between Parallel Surfaces, 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 are permitted to 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.

19.1.2 *Grain Size, Electrical Resistivity, Tensile and Yield Strength, and Rockwell Hardness*—These tests shall be reported as the average of results from two test specimens and each specimen shall conform to specification requirements.

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

19.2 *Retests:*

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

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 this specification's requirement(s) in retest and failure to conform shall be cause for lot rejection.

20. Specimen Preparation

20.1 *Chemical Analysis*—Preparation of the analytical specimens shall be the responsibility of the reporting laboratory.

20.2 *Tensile and Yield Strength Test*—The test specimens shall be of the full section of the tube and shall conform with the requirements of the Test Specimen section of Test Methods E 8, unless the limitation of the testing machine precludes the use of such specimen in which case test specimen conforming to Type No. 1 of Fig. 13 in Test Methods E 8 shall be used.

20.3 *Rockwell Hardness:*

20.3.1 The test specimen shall be of a size and shape to permit testing by the available test equipment.

20.3.2 The surface of the test specimen shall be sufficiently flat and smooth so as to permit the accurate determination of hardness.

20.3.3 The test specimen shall be free from scale and foreign matter and care shall be taken to avoid any change in condition, for example, heating or cold working.

20.4 *Grain Size*—Test specimens shall be prepared in accordance with the appropriate procedure in Test Methods E 3.

20.5 *Electrical Resistivity:*

20.5.1 The test specimen shall be full size and shall be the full cross section of the material it represents when possible.

20.5.2 When the test specimen is taken from material in bulk, care shall be taken that the properties are not appreciably altered in the preparation.

NOTE 4—Plastic deformation tends to work-harden a material and raise its resistivity, while heating tends to anneal the material with a subsequent reduction in resistivity.

20.5.2.1 When necessary, products are to be rolled or cold drawn to a wire approximately 0.080 in. in diameter (12 gage AWG) and of a convenient length. At least two specimens of a length sufficient to accommodate the testing equipment shall be cut from one end of the wire and annealed at approximately 935 ± 10°F for 30 min in an inert atmosphere and rapidly cooled to ambient temperature without undue exposure to air.

20.6 *Expansion (Pin) Test*—Test specimens shall conform to the requirements of the Specimen Preparation section of Test Method B 153.

20.7 *Microscopical Examination*—The test specimen shall be prepared in accordance with Procedure A of Test Methods B 577 and the specimen surface shall approximate a radial longitudinal section of round tube or a longitudinal section of rectangular and square tube perpendicular to, and bisecting, the major dimensional surface.

20.8 *Hydrogen Embrittlement*—The test specimen shall conform to the appropriate requirements of Procedure B of Test Methods B 577.

21. Test Methods

21.1 *Chemical Composition*—The copper composition shall be determined, in case of disagreement, as follows:

Element	Test Method
Copper	E 53
Phosphorus	E 62
Arsenic	E 62

21.1.1 The test methods for the determination of composition for Coppers C10100 and C10200 shall be as described in Annex A1 of Specification B 170.

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 and the purchaser.

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

Test	Test Method
Tensile Strength	E 8
Yield Strength	E 8
Rockwell Hardness	E 18
Grain Size	E 112
Electrical Resistivity	B 193
Expansion (pin test)	B 153
Electromagnetic Examination (Eddy Current)	E 243
Microscopical Examination Procedure A	B 577
Hydrogen Embrittlement Procedure B	B 577
Hydrostatic Pressure	B 75, 21.2.9
Pneumatic Pressure	B 75, 21.2.10

21.2.1 Tensile strength shall be determined in accordance with Test Methods E 8.

21.2.1.1 Whenever test results are obtained from both full-size and machined specimens and they differ, the test results from the full-size specimens shall prevail.

21.2.2 Yield strength shall be determined at 0.5 % extension-under-load.

21.2.3 Rockwell hardness shall be determined on the inside surface of the tube and a minimum of three readings shall be taken on each specimen, each at a different location.

21.2.3.1 When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values are permitted to be specified by agreement between the manufacturer and the purchaser.

21.2.4 Grain size shall be determined, in case of dispute, by the intercept method.

21.2.5 *Electrical Resistivity*—The limit of measurement uncertainty shall be ±0.30 % as a process control method and ±0.15 % as an umpire method.

21.2.6 *Microscopical Examination*—Cuprous oxide con-

tent shall be determined in accordance with Procedure A, or, in case of dispute, Procedure C, Closed Bend Test, of Test Methods B 577 shall be followed.

21.2.7 *Hydrogen Embrittlement*—Procedure B shall be followed, or, in case of dispute, Procedure C, Closed Bend Test, of Test Methods B 577 shall be followed.

21.2.8 *Electromagnetic (Eddy-Current) Test*—Each tube up to and including 3⅛ in. in outside diameter shall be subjected to an eddy-current test. Testing shall follow the procedures in Practice E 243. Tubes shall be passed through an eddy-current test unit adjusted to provide information on the suitability of the tube for the intended application.

21.2.8.1 Either notch depth or drilled hole standards shall be used.

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

(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 vary by more than +0.001, −0.000 in. 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

21.2.8.2 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 percent 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

21.2.8.3 Tubes that do not activate the signalling 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 are permitted, at the option of the manufacturer, to 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.

21.2.9 *Hydrostatic Test*—The internal hydrostatic pressure necessary to produce the required fiber stress shall be determined by the following equation for thin hollow cylinders under tension.

$$P = 2St/(D - 0.8t)$$

where:

P = hydrostatic pressure, psi (or MPa);
t = thickness of tube wall, in. (or mm);
D = outside diameter of tube, in. (or mm); and
S = allowable fiber stress of the material, psi (MPa).

21.2.9.1 The tube need not be tested at a pressure gage reading over 1000 psi unless so specified.

21.2.10 *Pneumatic Test*—The test method shall permit easy visual detection of leakage, such as having the material under water or by the pressure differential method.

22. Certification

22.1 Certification is mandatory when product is ordered for ASME Boiler and Pressure Vessel Code applications.

23. Keywords

23.1 seamless copper tube; seamless tube; tube

APPENDIXES

(Nonmandatory Information)

X1. RECOMMENDED APPLICATIONS

X1.1 Tube in the H55 temper is recommended when a tube of some stiffness is required yet capable of being bent when necessary.

X1.2 Tube in the H58 temper is recommended for general applications where there is no specific need for high strength or bending qualities.

X1.3 Tube in the H80 temper is recommended for applications where there is a need for a tube as strong as technically feasible for the size indicated.

X2. INTERNATIONAL ANNEALED COPPER STANDARD (ELECTRICAL CONDUCTIVITY EQUIVALENTS)

Electrical Resistivity, Ω•g/m²	Conductivity, %	Electrical Resistivity Ω•g/m²	Conductivity, %
0.15176	101.00	0.15940	96.16
0.15328	100.00	0.17031	90
0.15614	98.16	0.17418	88
0.15737	97.40		

SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification that have been incorporated since the 1992a issue, and the following are some of the changes incorporated in this revision:

(1) Ordering Information—Options available identified.
(2) General Requirements—The applicable sections of Specification B 251 identified.
(3) Number of Tests and Retests—The conditions under which retests are permitted are more definitively stated.
(4) Sampling and Specimen Preparation sections added.
(5) Test Methods—Individual test methods are identified and eddy-current parameters significantly revised.
(6) Recommended applications for the various tempers relocated from Temper section text to an appendix.
(7) Nonmandatory language deleted and replaced with mandatory language.

Designation: B 75M – 97
METRIC

Standard Specification for Seamless Copper Tube [Metric][1]

This standard is issued under the fixed designation B 75M; 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 specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope*

1.1 This specification[2] establishes the requirements for seamless round, rectangular, and square copper tube suitable for general engineering applications.

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.	Type of Copper
C10100	Oxygen-free electronic
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 The values stated in SI units are the standard.

1.3 This specification is the companion to inch-pound Specification B 75.

1.4 The following hazard statement pertains only to the test method described in Sections 20.5.2.1, 21.2.9, and 21.2.10 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 75 Specification for Seamless Copper Tube[3]
B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing[3]
B 170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes[3]
B 193 Test Method for Resistivity of Electrical Conductor Material[4]
B 251M Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube [Metric][3]
B 577 Test Methods for Hydrogen Embrittlement of Copper[3]
B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[3]
E 3 Test Methods of Preparation of Metallographic Specimens[5]
E 8M Test Methods for Tension Testing of Metallic Materials (Metric)[5]
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[5]
E 53 Test 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[5]
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 the Determination of Chemical Composition[6]
E 527 Practice for Numbering Metals and Alloys (UNS)[8]

3. Ordering Information

3.1 Orders for product shall include the following information:

3.1.1 ASTM designation and year of issue (for example, B 75M – 96),
3.1.2 Copper UNS No. (for example, C10100),
3.1.3 Temper (Section 8),
3.1.4 Dimensions; diameter or distance between parallel surfaces, and wall thickness (Section 15),
3.1.5 How furnished; coils or straight lengths,
3.1.6 Number of pieces or footage; each size and type,
3.1.7 Total weight,
3.1.8 When product is purchased for ASME Boiler and Pressure Vessel Code application, and
3.1.9 When product is purchased for agencies of the U.S. Government.

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

3.2.1 Electrical mass resistivity test,
3.2.2 Hydrogen embrittlement test,
3.2.3 Hydrostatic test,
3.2.4 Pneumatic test,

[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.

Current edition approved February 10, 1997. Published October 1997. Originally published as B 75M – 84. Last previous edition B 75M – 95.

[2] For *ASME Boiler and Pressure Vessel Code* applications refer to related Specification SB-75 in Section II of that Code.

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

[4] *Annual Book of ASTM Standards*, Vol 02.03.

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

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

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

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

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

TABLE 1 Chemical Requirements

Element	Composition, %						
	Copper UNS No.						
	C10100	C10200[A]	C10300	C10800	C12000	C12200	C14200
Copper[B], min	99.99	99.95	...	...	99.90	99.9	99.40
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	0.015–0.040
Arsenic	...	...	...	...	...	...	0.15–0.50

[A] Refer to Table 1, Chemical Requirements, Grade 1, of Specification B 170 for impurity limits for Copper UNS No. C10100.
[B] Refer to Table 1, Chemical Requirements, Grade 2, of Specification B 170 for impurity limits for Copper UNS No. C10200.

3.2.5 Certification, and
3.2.6 Test report.

4. General Requirements

4.1 The following sections of Specification B 251M are a part of this specification.
4.1.1 Terminology, General,
4.1.2 Material and Manufacturer,
4.1.3 Workmanship, Finish, and Appearance,
4.1.4 Significance of Numerical Limits,
4.1.5 Inspection,
4.1.6 Rejection and Rehearing,
4.1.7 Certification,
4.1.8 Mill Test Reports,
4.1.9 Packaging and Package Marking, and
4.1.10 Supplementary Requirements.

4.2 In addition, when a section with an identical title to those referenced in 4.1 appears in this specification, and is in conflict with the section appearing in Specification B 251M, the section in this specification shall prevail.

5. Terminology, Specific

5.1 *Definitions of Terms Specific to This Specification:*
5.1.1 *capable of*—the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.
5.1.2 *unaided eye*—without visual enhancement; however, corrective spectacles necessary to obtain normal vision shall be permitted.

6. Material and Manufacture

6.1 *Material*—The material of manufacture shall be billets, cast bars, or tube of Copper UNS[9] No. C10100, 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*—The tube shall be manufactured by such hot- and cold-working processes as to produce a homogeneous, uniform wrought structure in the finished product. It shall be cold drawn to the finished size and wall thickness. When cold-drawn temper is required, the final drawing operation shall be such as to meet the specified temper. When annealed temper is required, the tube shall be annealed subsequent to the final cold draw.

[9] Refer to Practice E 527 for explanation of Unified Numbering System (UNS).

7. Chemical Composition

7.1 The material shall conform to the requirements in Table 1 for the specified Copper UNS No. designation.

7.1.1 These specification limits do not preclude the presence of other elements. Limits are permitted to be established and analysis required for unnamed elements by agreement between the manufacturer or supplier and the purchaser.

8. Temper

8.1 The requirements and size availability of tube in the cold-drawn tempers H55, H58, and H80, as defined in Practice B 601, are specified in Table 2.

8.1.1 Rectangular, including square, tube shall normally be supplied only in H58 temper; however, tube in H55 or H80 temper is permitted to be supplied as agreed upon between the manufacturer and the purchaser.

8.1.1.1 For any combination of diameter and wall thickness not listed under H80 temper, the requirements specified for H58 temper shall apply.

8.2 The requirements and size availability of tube in the annealed tempers O50 and O60, as defined in Practice B 601, are specified in Table 2.

NOTE 1—The purchaser shall confer with the manufacturer or supplier for the availability of product in a specific temper.

NOTE 2—Refer to Appendix X1 for recommended applications based on temper.

9. Grain Size Requirements

9.1 Tube in the annealed temper shall conform to the grain size specified in Table 2.

10. Physical Property Requirements

10.1 *Electrical Resistivity*—When specified in the contract or purchase order, tube ordered for electrical conductor application produced from Copper UNS No. C10100, C10200, C10300, or C12000 shall have an electrical mass resistivity, $\Omega \cdot g/m^2$, not to exceed the following limit for the specified copper and temper when tested in accordance with Test Method B 193:

Temper	Copper UNS No.			
	C10100	C10200	C10300	C12000
O60, O50	0.15176	0.15328	0.15614	0.17031
H55, H58, H80	0.15614	0.15737	0.15940	0.17418

NOTE 3—Refer to Appendix X2 for the International Annealed Copper Standard (IACS) electrical conductivity equivalents.

11. Mechanical Property Requirements

11.1 *Tensile and Yield Strength:*

TABLE 2 Mechanical Property Requirements of Drawn-Temper and Annealed-Temper Tube

Temper Designation		Outside Diameter, or Major Distance Between Outside Parallel Surfaces, mm	Wall Thickness, mm	Rockwell Hardness		Average Grain Size, mm	Tensile Strength, MPa	Yield Strength,[A] min, MPa
Standard	Former			Scale	Hardness			
H55	Light-drawn[B]	all	all	30T[C]	30 to 60		250–325	205
H58	Drawn (general purpose)	all	all	30T[C]	30 min		250 min	205
H80	Hard-drawn[B]	up to 102	0.508 to 6.35, incl	30T[C]	55 min		310 min	275
O60	Soft anneal	all	0.381 to 0.889	15T[D]	60 max	0.040 min	205 min	62[E]
			0.889 and over	F[D]	50 max	0.040 min	205 min	62[E]
O50	Light anneal	all	0.381 to 0.889	15T[D]	65 max	0.040 max	205 min	62[E]
			0.889 and over	F[D]	55 max	0.040 max	205 min	62[E]

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

[B] Light-drawn and hard-drawn tempers are normally available in round tubes only.

[C] Rockwell hardness values shall apply only to tubes having a wall thickness of 0.508 mm or over, to round tubes having an inside diameter of 8.0 mm or over, and to rectangular including square tubes having an inside major distance between parallel surfaces of 5.0 mm or over. Rockwell hardness tests shall be made on the inside surface of the tube. When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values are permitted to be specified to agreement between purchaser and supplier.

[D] Rockwell hardness values shall apply only to tubes having a wall thickness of 0.40 mm or over, to round tubes having an inside diameter of 8.0 or over, and to rectangular including square tubes having an inside major distance between parallel surfaces of 5.0 mm or over. For all other tube no Rockwell values shall apply. Rockwell hardness tests shall be made on the inside surface of the tube. When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values are permitted to be specified subject to agreement between purchaser and supplier.

[E] Light straightening operation is permitted.

11.1.1 The tube shall conform to the requirements of Table 2 for the specified temper and wall thickness.

11.1.2 For any combination of diameter and wall thickness not listed under H80, the requirements for H58 shall apply.

11.2 *Rockwell Hardness:*

11.2.1 The tube shall conform to the requirements of Table 2 for the specified temper and wall thickness.

11.2.1.1 The Rockwell Hardness values for tube in the H55, H58, and H80 temper shall apply only to the following:

(a) Tubes having a wall thickness of 0.508 mm and over,

(b) Round tubes having an inside diameter of 8.0 mm and over,

(c) Rectangular and square tubes having major distances between parallel surfaces of 5 mm and over.

11.2.1.2 The Rockwell Hardness values for tube in the O60 and O50 temper shall apply only to the following:

(a) Tubes having a wall thickness of 0.40 mm and over;

(b) Round tubes having an inside diameter of 8 mm and over;

(c) Rectangular and square tubes having inside major distances between parallel surfaces of 5 mm and over.

11.3 *Straightening*—Light straightening is permitted for tube in the O60 and O50 temper.

12. Performance Requirements

12.1 *Expansion Test for Round Tube*—When specified in the contract or purchase order, annealed tubes shall be capable of withstanding an expansion of the outside diameter of 40 % for tube 19.0 mm and under and 30 % for tube over 19.0 mm. The tube shall show no cracking or rupture visible to the unaided eye.

13. Microscopical Examination

13.1 Tubes furnished in Copper UNS No. C10100, C10200, C10300, and C12000 shall be essentially free of cuprous oxide as determined by Procedure A of Test Methods B 577.

14. Hydrogen Embrittlement

14.1 When specified in the contract or purchase order, tubes produced in all designated copper material shall be capable of conforming to the requirements of Procedure B of Test Methods B 577.

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 B 251M.

16. Nondestructive Test

16.1 The tubes shall be tested in the drawn tempers or as drawn prior to the final-annealed temper unless otherwise agreed upon between the manufacturer and the purchaser.

16.2 *Electromagnetic (Eddy Current) Test:*

16.2.1 Each tube up to and including 79 mm in outside diameter shall be subjected to test.

16.2.2 When tested in accordance with Practice E 243, tubes which do not actuate the signaling device of the testing unit shall be considered as conforming to the requirements of the test.

16.3 *Hydrostatic Pressure Test*—When specified in the contract or purchase order, each tube shall be capable of withstanding an internal hydrostatic pressure sufficient to produce a fiber stress of 41 MPa without leakage. The tube need not be subjected to a pressure gage reading over 6.9 MPa unless specifically stipulated in the contract or purchase order.

16.4 *Pneumatic Pressure Test*—When specified in the contract or purchase order, each tube shall be capable of withstanding an internal air pressure of 400 kPa, minimum, for 5 s without leakage.

17. Dimensions, Mass, and Permissible Variations

17.1 The dimensions and tolerances for product furnished to this specification shall be as specified in the following tables and related sections of the current edition of Specification B 251M:

17.1.1 *Wall Thickness Tolerances*—Refer to Tables 1 and 2.

TABLE 3 Coil Length Tolerances (Specific Lengths)

Outside Diameter or Major Distance Between Parallel Surfaces, mm	Tolerances, mm, All Plus, for Nominal Lengths, m	
	Up to 15, incl	Over 15 to 30, incl
Up to 50.8, incl	300	610

17.1.2 *Tolerances for Diameter or Distance Between Parallel Surfaces*—Refer to Tables 3 and 4.

17.1.3 *Length Tolerances*—Refer to Tables 5 and 6.

17.1.4 *Straightness Tolerance*—Refer to Table 7.

17.1.5 *Corner Radius for Rectangular Including Square Tube*—Refer to Table 8.

17.1.6 *Roundness, Squareness of Cut and Twist Tolerances for Rectangular and Square Tubes*—Refer to titled sections.

17.2 *Length Tolerances for Tube in Coils*—Refer to Tables 3, 4, and 5 of Specification B 75M.

18. Sampling

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

18.1.1 *Lot Size*—An inspection lot shall be 5000 kg or fraction thereof,

18.1.2 *Portion Size*—Sample pieces shall be selected to be represented of the lot as follows:

Number of Pieces in Lot	Number of Portions to Be Taken[A]
1 to 50	1
51 to 200	2
201 to 1500	3

[A] Each test portion shall be taken from a separate tube.

18.2 *Chemical Composition:*

18.2.1 The composite sample shall be taken in approximate equal weights from each portion piece selected in 18.1.2 and in accordance with Practice E 255. The minimum weight of the composite shall be 150 g.

18.2.2 The manufacturer shall have the option of sampling at the time the castings are poured or taken from the semifinished product. The number of samples taken during the course of manufacture shall be as follows:

18.2.2.1 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.

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

18.2.2.3 When composition is determined during the course of manufacture, sampling and analyses of the finished product is not required.

18.3 *Other Tests*—Specimens for all other tests shall be taken from two of the sample portions taken in 18.1.2. In the event only one sample portion is taken, all specimens shall be taken from the portion selected.

19. Number of Tests and Retests

19.1 *Tests:*

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

19.1.2 *Grain Size, Electrical Resistivity, Tensile and Yield Strength, and Rockwell Hardness*—These tests shall be reported as the average of results from two test specimens and each specimen shall conform to specification requirements.

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

19.2 *Retests:*

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

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 this specification's requirement(s) in retest and failure to conform shall be cause for lot rejection.

20. Specimen Preparation

20.1 *Chemical Analysis*—Preparation of the analytical

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

Tube Outside Diameter or Major Distance Between Parallel Surfaces, mm	Tolerances, %, for Nominal Lengths in mm	
	up to 30 000, incl	over 30 000 to 600 000, incl
Up to 25, incl	5[A] or 600, whichever is greater	10[A]
25 to 50, incl	5[A] or 600, 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 or Major Distance Between Parallel Surfaces, mm	Nominal Length, mm	Shortest Permissible Length, % of Nominal Length	Maximum Permissible Mass 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 600 000, incl	50	50[B]

[A] Expressed to the nearest 300.

[B] Short pieces are permitted to be included as follows: up to 10 % of lot weight between 15 200 and one quarter of full length: and up to 40 % between one quarter and full length.

specimens shall be the responsibility of the reporting laboratory.

20.2 *Tensile and Yield Strength Test*—The test specimens shall be of the full section of the tube and shall conform with the requirements of the Test Specimen section of Test Methods E 8M, unless the limitation of the testing machine precludes the use of such specimen in which case test specimen conforming to Type No. 1 of Fig. 13 in Test Methods E 8M shall be used.

20.3 *Rockwell Hardness:*

20.3.1 The test specimen shall be of a size and shape to permit testing by the available test equipment.

20.3.2 The surface of the test specimen shall be sufficiently flat and smooth so as to permit the accurate determination of hardness.

20.3.3 The test specimen shall be free from scale and foreign matter and care shall be taken to avoid any change in condition, that is, heating or cold working.

20.4 *Grain Size*—Test specimens shall be prepared in accordance with the appropriate procedure in Test Methods E 3.

20.5 *Electrical Resistivity:*

20.5.1 The test specimen shall be full size and shall be the full cross section of the material it represents when possible.

20.5.2 When the test specimen is taken from material in bulk, care shall be taken that the properties are not appreciably altered in the preparation.

NOTE 4—Plastic deformation tends to work-harden a material and raise its resistivity, while heating tends to anneal the material with a subsequent reduction in resistivity.

20.5.2.1 When necessary, products are to be rolled or cold drawn to a wire approximately 2 mm in diameter (12 gage AWG) and of a convenient length. At least two specimens of a length sufficient to accommodate the testing equipment shall be cut from one end of the wire and annealed at approximately 500 ± 5°C for 30 min in an inert atmosphere and rapidly cooled to ambient temperature without undue exposure to air.

20.6 *Expansion (Pin) Test*—Test specimens shall conform to the requirements of the Specimen Preparation section of Test Method B 153.

20.7 *Microscopical Examination*—The test specimen shall be prepared in accordance with Procedure A of Test Methods B 577 and the specimen surface shall approximate a radial longitudinal section of round tube or a longitudinal section of rectangular and square tube perpendicular to, and bisecting, the major dimensional surface.

20.8 *Hydrogen Embrittlement*—The test specimen shall conform to the appropriate requirements of Procedure B of Test Methods B 577.

21. Test Methods

21.1 *Chemical Composition*—The copper composition shall be determined, in case of disagreement, as follows:

Element	Test Methods
Copper	E 53
Phosphorus	E 62
Arsenic	E 62

21.1.1 The test methods for the determination of composition for Coppers C10100 and C10200 shall be as described in Annex A1 of Specification B 170.

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 and the purchaser.

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

Test	Test Method
Tensile Strength	E 8M
Yield Strength	E 8M
Rockwell Hardness	E 18
Grain Size	E 112
Electrical Resistivity	B 193
Expansion (pin test)	B 153
Electromagnetic Examination (Eddy Current)	E 243
Microscopical Examination Procedure A	B 577
Hydrogen Embrittlement Procedure B	B 577
Hydrostatic Pressure	B 75M, 21.2.9
Pneumatic Pressure	B 75M, 21.2.10

21.2.1 Tensile strength shall be determined in accordance with Test Methods E 8M.

21.2.1.1 Whenever test results are obtained from both full-size and machined specimens and they differ, the test results from the full-size specimens shall prevail.

21.2.2 Yield strength shall be determined at 0.5 % extension-under-load.

21.2.3 Rockwell hardness shall be determined on the inside surface of the tube and a minimum of three readings shall be taken on each specimen, each at a different location.

21.2.3.1 When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values are permitted to be specified by agreement between the manufacturer and the purchaser.

21.2.4 Grain size shall be determined, in case of dispute, by the intercept method.

21.2.5 *Electrical Resistivity*—The limit of measurement uncertainty shall be ±0.30 % as a process control method and ±0.15 % as an umpire method.

21.2.6 *Microscopical Examination*—Cuprous oxide content shall be determined in accordance with Procedure A, or, in case of dispute, Procedure C, Closed Bend Test, of Test Methods B 577 shall be followed.

21.2.7 *Hydrogen Embrittlement*—Procedure B shall be followed, or, in case of dispute, Procedure C, Closed Bend Test, of Test Methods B 577 shall be followed.

21.2.8 *Electromagnetic (Eddy-Current) Test*—Each tube up to and including 79 mm in outside diameter, shall be subjected to an eddy-current test. Testing shall follow the procedures in Practice E 243. Tubes shall be passed through an eddy-current test unit adjusted to provide information on the suitability of the tube for the intended application.

21.2.8.1 Either notch depth or drilled hole standards shall be used.

(a) Notch depth standards, rounded to the nearest 0.025 mm shall be 22 % of the wall thickness. The notch depth tolerance shall be ±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 vary by more than +0.025 mm, −0.000 mm of the hole diameter specified.

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

21.2.8.2 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 percent maximum imbalance signals shall be used:

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

21.2.8.3 Tubes that do not activate the signalling 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 are permitted, at the option of the manufacturer, to be reexamined or retested to determine whether the discontinuing 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.

21.2.9 *Hydrostatic Test*—The internal hydrostatic pressure necessary to produce the required fiber stress shall be determined by the following equation for thin hollow cylinders under tension.

$$P = 2St/(D - 0.8t) \quad (1)$$

where:

P = hydrostatic pressure, MPa;
t = thickness of tube wall, mm;
D = outside diameter of tube, mm, and;
S = allowable fiber stress of the material, MPa.

21.2.9.1 The tube need not be tested at a pressure gage reading over 6.9 MPa unless so specified.

21.2.10 *Pneumatic Test*—The test method shall permit easy visual detection of leakage, such as having the material under water or by the pressure differential method.

22. Certification

22.1 Certification is mandatory when product is ordered for ASME Boiler and Pressure Vessel Code applications.

23. Keywords

23.1 seamless copper tube; seamless tube; tube

APPENDIXES

(Nonmandatory Information)

X1. RECOMMENDED APPLICATIONS

X1.1 Tube in the H55 temper is recommended when a tube of some stiffness is required yet capable of being bent when necessary.

X1.2 Tube in the H58 temper is recommended for general applications where there is no specific need for high strength or bending qualities.

X1.3 Tube in the H80 temper is recommended for applications where there is a need for a tube as strong as technically feasible for the size indicated.

X2. INTERNATIONAL ANNEALED COPPER STANDARD (ELECTRICAL CONDUCTIVITY EQUIVALENTS)

Electrical Resistivity, Ω·g/m²	Conductivity, %	Electrical Resistivity, Ω·g/m²	Conductivity, %
0.15176	101.00	0.15940	96.16
0.15328	100.00	0.17031	90
0.15614	98.16	0.17418	88
0.15737	97.40		

SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification that have been incorporated since the 1992a issue, and the following are some of the changes incorporated in this revision:

(1) Ordering Information—Options available identified.
(2) General Requirements—The applicable sections of Specification B 251M identified.
(3) Number of Tests and Retests—The conditions under which retests are permitted are more definitively stated.
(4) Sampling and Specimen Preparation sections added.
(5) Test Methods—Individual test methods are identified and eddy-current parameters significantly revised.
(6) Recommended applications for the various tempers relocated from Temper section text to an appendix.
(7) Nonmandatory language has been deleted and replaced with mandatory language.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name:

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APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 85 – 84

Standard Specification for Aluminum-Alloy Die Castings[1]

This standard is issued under the fixed designation B 85; 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 specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification covers aluminum-alloy die castings. Ten alloy compositions are specified, designated as shown in Table 1.

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

2. Referenced Documents

2.1 The following documents of the issue in effect on date of order acceptance form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*

B 179 Specification for Aluminum Alloys in Ingot Form for Sand Castings, Permanent Mold Castings, and Die Castings[2]

B 275 Practice for Codification of Certain Nonferrous Metals and Alloys, Cast and Wrought[2]

E 8 Methods of Tension Testing of Metallic Materials[3]

E 23 Method for Notched-Bar Impact Testing of Metallic Materials[3]

E 29 Recommended Practice for Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values[4]

E 34 Method for Chemical Analysis of Aluminum and Aluminum Alloys[5]

E 88 Practice for Sampling Nonferrous Metals and Alloys in Cast Form for Determination of Chemical Composition[5]

E 101 Method for Spectrographic Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[6]

E 227 Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[6]

E 505 Reference Radiographs for Inspection of Aluminum and Magnesium Die Castings[7]

E 527 Practice for Numbering Metals and Alloys (UNS)[3]

2.3 *American National Standards Institute:*

H35.1 Alloy and Temper Designation Systems for Aluminum[2]

2.4 *American Die Casting Institute:*

"E" Series Product Standards for Die Castings[2]

2.5 *Federal Standards:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[8]

Fed. Std. No. 184 Identification Marking of Aluminum, Magnesium and Titanium[8]

2.6 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage (Military Agencies)[8]

MIL-STD-649 Preparation for Storage and Shipment of Aluminum and Magnesium Products[8]

3. Definitions

3.1 *die casting*—a metal object produced by the introduction of molten metal under substantial pressure into a metal die and characterized by a high degree of fidelity to the die cavity.

4. Ordering Information

4.1 Orders for die castings shall include the following basic information:

4.1.1 This specification number and date,

4.1.2 Quantity and delivery schedule, as required,

4.1.3 Part name and number,

4.1.4 Alloy (Table 1), and

4.1.5 Drawing of die casting, when required, giving all necessary dimensions and showing latest revisions and allowances for machining, if any. Location of ejector pin marks or parting lines shall be at the option of the producer; unless specifically designated on the drawing.

4.2 Additional tests, options and special inspection requirements as provided below should be justified only on the basis of need. These shall be specified in the contract or purchase order, as additional procedures and extended delivery time may be involved.

4.2.1 Chemical analysis (7.1.1),

4.2.2 Quality assurance (Section 6),

4.2.3 Special proof tests or mechanical properties (Section 8),

4.2.4 General quality options for internal soundness or for finish (Section 10),

4.2.5 Source inspection (Section 11),

4.2.6 Certification (Section 12),

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[1] This specification is under the jurisdiction of ASTM Committee B-6 on Die-Cast Metals and Alloys, and is the direct responsibility of Subcommittee B06.01 on Aluminum Die Castings.

Current edition approved March 30, 1984. Published May 1984. Originally published as B 85 – 31 T. Last previous edition B 85 – 82a.

[2] *Annual Book of ASTM Standards*, Vol 02.02.

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

[4] *Annual Book of ASTM Standards*, Vol 14.02.

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

[6] *Annual Book of ASTM Standards*, Vol 03.06.

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

[8] Available from Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120.

TABLE 1 Chemical Requirements [A,B,C]

Alloy [D]			Composition %										
ANSI	ASTM	UNS	Silicon	Iron	Copper	Manganese	Magnesium	Nickel	Zinc	Tin	Titanium	Other Constituents, Except Aluminum (Total)	Aluminum
360.0	SG100B	A03600	9.0–10.0	2.0	0.6	0.35	0.40–0.6	0.50	0.50	0.15	...	0.25	remainder
A360.0	SG100A	A13600	9.0–10.0	1.3	0.6	0.35	0.40–0.6	0.50	0.50	0.15	...	0.25	remainder
380.0	SC84B	A03800	7.5–9.5	2.0	3.0–4.0	0.50	0.10	0.50	3.0	0.35	...	0.50	remainder
A380.0[E]	SC84A	A13800	7.5–9.5	1.3	3.0–4.0	0.50	0.10	0.50	3.0	0.35	...	0.50	remainder
383.0[E]	SC102A	A03830	9.5–11.5	1.3	2.0–3.0	0.50	0.10	0.30	3.0	0.15	...	0.50	remainder
384.0[E]	SC114A	A03840	10.5–12.0	1.3	3.0–4.5	0.50	0.10	0.50	3.0	0.35	...	0.50	remainder
390.0	SC174A	A03900	16.0–18.0	1.3	4.0–5.0	0.10	0.45–0.65	...	0.10	...	0.20	0.20	remainder
B390.0	SC174B	A23900	16.0–18.0	1.3	4.0–5.0	0.50	0.45–0.65	0.10	1.5	...	0.10	0.20	remainder
392.0	S19	A03920	18.0–20.0	1.5	0.40–0.80	0.20–0.60	0.80–1.20	0.50	0.50	0.30	0.20	0.50	remainder
413.0	S12B	A04130	11.0–13.0	2.0	1.0	0.35	0.10	0.50	0.50	0.15	...	0.25	remainder
A413.0	S12A	A14130	11.0–13.0	1.3	1.0	0.35	0.10	0.50	0.50	0.15	...	0.25	remainder
C443.0	S5C	A34430	4.5–6.0	2.0	0.6	0.35	0.10	0.50	0.50	0.15	...	0.25	remainder
518.0	G8A	A05180	0.35	1.8	0.25	0.35	7.5–8.5	0.15	0.15	0.15	...	0.25	remainder

[A] Analysis shall ordinarily be made only for the elements mentioned in this table. If, however, the presence of other elements is suspected, or indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements are not present in excess of specified limits.

[B] For purposes of acceptance and rejection, the observed value or calculated value obtained from analysis should be rounded off to the nearest unit in the last right-hand place of figures, used in expressing the specified limit, in accordance with the rounding procedure prescribed in Section 3 of Recommended Practice E 29.

[C] Limits are in percent maximum unless shown otherwise.

[D] Alloys 360.0, 380.0, 413.0, C443.0 and 518.0 are suitable for the production of die casting by either the hot-chamber or the cold-chamber process. Die castings of alloys A360.0, A380.0, 383,0, 384.0 and A413.0 may be made only in cold-chamber machines.

ASTM designations were established in accordance with Recommended Practice B 275. ANSI designations were established in accordance with ANSI H35.1. UNS designations were established in accordance with Recommended Practice E 527.

[E] With respect to mechanical properties, alloys A380.0, 383.0 and 384.0 are substantially interchangeable.

4.2.7 Marking for identification (Section 14), and

4.2.8 Special packaging (Section 15).

5. Materials

5.1 The aluminum alloys used for the manufacture of die castings shall be such that the die castings produced will conform to the chemical composition requirements of this specification.

6. Quality Assurance

6.1 *Responsibility for Inspection*—When specified in the contract or purchase order, the producer or supplier is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract or order, the producer or supplier may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification. Quality assurance standards shall be agreed upon between the producer or supplier and purchaser at the time a contract or order is placed.

6.2 *Lot Definition*—An inspection lot shall be defined as follows:

6.2.1 An inspection lot shall consist of the production from each die or compound die on each machine for each 24 h during the first week of normal operation and the production for each 48 h thereafter of normal operation. Any significant change in the machine, composition, die or continuity of operation shall be considered as the start of a new lot. Die castings inspected by this method shall be so marked or handled during the finishing operations as not to lose their identity.

6.2.2 Each die casting of a randomly selected sample shall be examined to determine conformance to the requirements with respect to general quality, dimensions, and identification marking. The producer or supplier may use a system of statistical quality control for such examinations.

7. Chemical Requirements

7.1 *Limits*—The die castings shall conform to the requirements as to chemical composition prescribed in Table 1. Conformance shall be determined by the producer by analyzing samples taken at the time castings are made. If the producer has determined the chemical composition of the metal during the course of manufacture, he shall not be required to sample and analyze the finished product.

7.1.1 When a detailed chemical analysis is required with a shipment, it shall be called for in the contract or purchase order.

7.1.2 If the producer's or supplier's method of composition control is acceptable, sampling for chemical analysis may be waived at the discretion of the purchaser.

7.2 *Number of Samples*—When required, samples for determination of chemical composition shall be taken to represent the following:

7.2.1 A sample shall be taken from each of two representative castings selected from each lot defined in 6.2.1.

7.3 *Methods of Sampling*—Samples from die castings for determination of chemical composition shall be taken in accordance with one of the following methods:

7.3.1 Samples for chemical analysis shall be taken from the material by drilling, sawing, milling, turning, or clipping a representative piece or pieces to obtain a weight of prepared sample not less than 75 g. Sampling shall be in accordance with Practice E 88.

7.3.2 By agreement, an appropriate spectrographic sample may be prepared at time of manufacture.

7.3.3 The method of sampling cast products for spectrochemical and other methods of analysis shall be suitable for the form of material being analyzed and the type of analytical method used.

7.4 *Method of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (Methods E 34), spectrochemical (Method E 101 or E 227), or other methods. In case of dispute, the results secured by Methods E 34 shall be the basis of acceptance.

8. Mechanical Properties and Tests

8.1 Unless specified in the contract or purchase order or specifically guaranteed by the manufacturer, acceptance of die castings under these specifications shall not depend on mechanical properties determined by tension or impact tests. Table X1.1 shows typical mechanical properties. When tension or impact tests are made, the tension test specimen shown in Fig. 18 of Methods E 8 and the impact test specimen shown in Fig. 6 of Methods E 23 shall be used.

8.2 When specified in the contract or purchase order, die castings shall withstand proof tests without failure as defined by agreement between the purchaser and the producer or supplier.

9. Permissible Variations in Dimensions

9.1 Permissible variations in dimensions shall be within the limits specified on the drawings or in the contract or purchase order.

9.1.1 Any dimensions for which a tolerance is not specified shall be in accordance with ADCI Product Standard Series E 1 to E 16 inclusive.

9.2 Dimensional tolerance deviations waived by the purchaser shall be confirmed in writing to the producer or supplier.

10. General Quality

10.1 *Internal Soundness*—When specified, the soundness of die castings shall conform to standards or requirements agreed upon between the producer or supplier and the purchaser. The number and extent of imperfections shall not exceed those specified by the purchaser. The standards or requirements may consist of radiographs in accordance with Method E 505, photographs or sectioned die castings.

10.2 Imperfections inherent in die castings shall not be cause for rejection provided it is demonstrated that the die castings are in accordance with the requirements and standards agreed upon.

10.3 *Workmanship*—Die castings shall be of uniform quality, free of injurious discontinuities that will adversely affect their serviceability.

10.4 *Finish*—When specified in the contract or purchase order the as-cast surface finish required shall conform to standards agreed upon between the purchaser and the producer or supplier, or as prescribed in ADCI Product Standard E 18.

10.5 *Pressure Tightness*—When specified in the contract or purchase order the pressure tightness of die castings shall conform to standards agreed upon between the purchaser and the producer or supplier, or as prescribed in ADCI Product Standard E 17.

11. Source Inspection

11.1 If the purchaser desires that his representative inspect or witness the inspection and testing of the product prior to shipment, such agreement shall be made by the purchaser and producer or supplier as part of the contract or purchase order.

11.2 When such inspection or witness of inspection and testing is agreed upon, the producer or supplier shall afford the purchaser's representative all reasonable facilities to satisfy him that the product meets the requirements of this specification. Inspection and tests shall be conducted so there is no unnecessary interference with the producer's operations.

12. Certification

12.1 The producer or supplier shall, when called for in the contract or purchase order, furnish to the purchaser a certificate of inspection stating that each lot has been sampled, tested, and inspected in accordance with this specification, and has been found to meet the requirements specified.

13. Rejection and Retest

13.1 When one or more samples, depending on the approved sampling plan, fail to meet the requirements of this specification, the represented lot is subject to rejection except as otherwise provided in 13.2.

13.2 Lots rejected for failure to meet the requirements of this specification may be resubmitted for test provided:

13.2.1 The producer has removed the nonconforming material or the producer has reworked the rejected lot as necessary to correct the deficiencies.

13.3 Individual castings that show injurious imperfections during subsequent manufacturing operations may be rejected. The producer or supplier shall be responsible only for replacement of the rejected castings to the purchaser. As much of the rejected original material as possible shall be returned to the producer or supplier.

14. Identification Marking

14.1 When specified in the contract or purchase order, all castings shall be properly marked for identification with the part number, name or brand of the producer, as agreed upon. Government applications shall be marked in accordance with Fed. Std. No. 184.

15. Preparation for Delivery

15.1 *Packaging*—Unless otherwise specified, the die castings shall be packaged to provide adequate protection during normal handling and transportation. Each package shall contain only one type of item unless otherwise agreed upon. The type of packaging and gross weight of containers shall, unless otherwise agreed upon, be at the producer's discretion, provided they are such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

15.2 *Marking*—Each shipping container shall be legibly marked with the purchase order number, gross and net weights, and the supplier's name or trademark. Marking for shipment shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for Military agencies.

15.3 *Preservation*—Material intended for prolonged storage in unheated locations shall be adequately packed and protected to avoid deterioration and damage. When specified in the contract or purchase order, material shall be preserved,

packaged, and packed in accordance with the requirements of MIL-STD-649. The applicable levels shall be as specified in the contract or order.

16. Characteristics of Die Casting Alloys

16.1 Table X1.1 shows certain casting and other outstanding characteristics which are usually considered in selecting a die-casting alloy for a specific application. The characteristics are rated from *(1) to (5)*, *(1)* being the best and *(5)* being the least desirable alloy. In applying these ratings, it should be noted that all the alloys have sufficiently good characteristics to be accepted by users and producers of die castings. Hence a rating of *(5)* indicates a commercial alloy, although in certain cases its application may be limited or its manufacture may be restricted to relatively simple castings.

APPENDIXES

(Nonmandatory Information)

X1. CHARACTERISTICS

X1.1 Table X1.1 shows certain casting and other outstanding characteristics which are usually considered in selecting a die casting alloy for a specific application.

TABLE X1.1 Die Casting and Other Characteristics

NOTE—*Rating System*—the various alloys are rated 1 to 5 according to the positive to negative qualities in the listed categories. A rating of 1 gives the best performance, 5 the poorest performance. No one alloy is best in all categories. A rating of 5 in any one or more categories does not rule an alloy out of commercial usefulness if its other attributes are especially favorable. However, ratings of 5 may present manufacturing difficulties.

Alloy				Die Casting Characteristics				Other Characteristics[M]						
ANSI[L]	ASTM[L]	UNS[L]	Approximate Melting Temperature Range, °F	Resistance to Hot Cracking[A]	Pressure Tightness	Die Filling Capacity[B]	Anti-Soldering to the Die[E]	Resistance to Corrosion[D]	Machining[C]	Polishing[F]	Electroplating[G]	Anodizing (Appearance)[H]	Chemical Oxide Coating (Protection)[I]	Strength of Elevated Temperatures[J]
360.0	SG100B	A03600	1035–1105	1	2	3	2	2	3	3	2	3	3	1
A360.0	SG100A	A13600	1035–1105	1	2	3	2	2	3	3	2	3	3	1
380.0	SC84B	A03800	1000–1100	2	2	2	1	4	3	3	1	3	4	3
A380.0	SC84A	A13800	1000–1100	2	2	2	1	4	3	3	1	3	4	3
383.0	SC102A	A03830	960–1080	1	2	1	2	3	2	3	1	3	4	2
384.0	SC114A	A03840	960–1080	2	2	1	2	5	3	3	2	4	5	2
390.0	SC174A	A03900	945–1200	4	4	1	2	3	5	5	3	5	5	3
B390.0	SC174B	A23900	950–1200	4	4	1	2	3	5	5	3	5	5	3
392.0	S19	A03920	1025–1245	4	3	1	2	2	5	5	3	5	5	3
413.0	S12B	A04130	1065–1080	1	1	1	1	2	4	5	3	5	3	3
A413.0	S12A	A14130	1065–1080	1	1	1	1	2	4	5	3	5	3	3
C443.0	S5C	A34430	1065–1170	3	3	4	4	2	5	4	2	2	2	5
518.0	G8A	A05180	995–1150	5	5	5	5	1	1	1	5	1	1	4

[A] Ability of alloy to withstand stresses from contraction while cooling through hot-short or brittle temperature range.
[B] Ability of molten alloy to flow readily in die and fill thin sections.
[C] Ability of molten alloy to flow without sticking to the die surfaces. Ratings given for antisoldering are based on nominal iron compositions of approximately 1.
[D] Based on resistance of alloy in standard type salt spray test.
[E] Composite rating based on ease of cutting, chip characteristics, quality of finish and tool life.
[F] Composite rating based on ease and speed of polishing and quality of finish provided by typical polishing procedure.
[G] Ability of the alloy to take and hold an electroplate applied by present standard methods.
[H] Rated on lightness of color, brightness and uniformity of clear anodized coating applied in sulphuric acid electrolyte. Generally aluminum die castings are unsuitable for light color anodizing where pleasing appearance is required.
[I] Rated on combined resistance of coating and base alloy to corrosion.
[J] Rating based on tensile and yield strengths at temperature up to 500°F (260°C), after prolonged heating at testing temperature.
[K] Die castings are not usually solution heat treated. Low temperature aging treatments may be used for stress relief or dimensional stability. Die castings are not generally gas or arc welded or brazed.
[L] ASTM designations were established in accordance with Recommended Practice B 275. ANSI designations were established in accordance with ANSI H 35.1. UNS designations were established in accordance with Recommended Practice E 527.

X2. MECHANICAL PROPERTIES

X2.1 The data in Table X2.1 do not constitute a part of this specification because the data only indicates mechanical properties that may be expected of test specimens when cast in a separate tensile test bar die and that conform to the chemical composition specified. Different machines and dies continue to be necessary for die castings and test bars. Comparison between static breakdown or proof tests and the mechanical properties of separately die cast test bars will show that test bars made in a different machine in a different die have no correlation with the die casting other than a common chemical composition. It should be thoroughly understood that the data in Table X2.1 represent die-cast test specimens and not specimens cut from commercial die-cast parts. For this reason, it is considered that the only practical method for mechanical property control is proof testing the whole die casting.

TABLE X2.1 Typical Mechanical Properties Test Specimens[A]

Alloy		UNS[B]	Tensile Strength, ksi (MPa)	Yield Strength (0.2 % Offset), ksi (MPa)	Elongation in 2 in. or 50 mm, %	Shear Strength, ksi (MPa)	Fatigue Strength (R. R. Moore Specimen), 500,000,000 cycles, ksi (MPa)
ANSI[A]	ASTM[B]						
360.0	SG100B	A03600	44(300)	25(170)	2.5	28(190)	20(140)
A360.0	SG100A	A13600	46(320)	24(170)	3.5	26(180)	18(120)
380.0	SC84B	A03800	46(320)	23(160)	2.5	28(190)	20(140)
A380.0	SC84A	A13800	47(320)	23(160)	3.5	27(190)	20(140)
383.0	SC102A	A03830	45(310)	22(150)	3.5	...	...
384.0	SC114A	A03840	48(330)	24(170)	2.5	29(200)	20(140)
390.0	SC174A	A03900	40.5(280)	35.0(240)	<1	...	...
B390.0	SC174B	A23900	46.0(320)	36.0(250)	<1	...	...
392.0	S19	A03920	42.0(290)	39.0(270)	<1	...	...
413.0	S12B	A04130	43(300)	21(140)	2.5	25(170)	19(130)
A413.0	S12A	A14130	42(290)	19(130)	3.5	25(170)	19(130)
C443.0	S5C	A34430	33(230)	14(100)	9.0	19(130)	17(120)
518.0	G8A	A05180	45(310)	28(190)	5	29(200)	20(140)

[A] See Appendix X3 for explanation of SI unit MPa.
[B] ASTM designations were established in accordance with Recommend Practice B 275. ANSI designations were established in accordance with ANSI H35.1. UNS designations were established in accordance with Recommended Practice E 527.

X3. METRIC EQUIVALENTS

X3.1 The SI unit for strength properties (MPa) 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.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B88: Standard Specification for Seamless Copper Water Tube

CFR Section(s): 46 CFR 56.60-1(b)

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 88 – 96

Standard Specification for Seamless Copper Water Tube[1]

This standard is issued under the fixed designation B 88; 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. Replaces WW-T-799. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers Copper UNS No. C12200 seamless copper water tube suitable for general plumbing, and similar applications for the conveyance of fluids, and commonly used with solder, flared, or compression type fittings. The type of copper water tube suitable for any particular application is determined by the internal or external fluid pressure, by the installation and service conditions, and by local requirements. Means of joining or bending are also factors which affect the selection of the type of tube to be used.[2]

NOTE 1—Annealed tube is suitable for use with flared or compression fittings, and with solder-type fittings, provided rounding and sizing of the tube ends is performed where needed.

NOTE 2—Drawn temper tube is suitable for use with solder-type fittings. Types K and L tube, in the drawn temper, are suitable for use with certain types and sizes of compression fittings.

NOTE 3—A complete metric companion to Specification B 88 has been developed—B 88M; therefore, no metric equivalents are presented in this specification.

NOTE 4—Fittings used for soldered or brazed connections in plumbing systems are described in ASME B16.18 and ASME 16.22.

1.2 The assembly of copper plumbing or fire sprinkler systems by soldering is described in Practice B 828.

1.3 Solders for joining copper potable water or fire sprinkler systems are covered by Specification B 32. The requirements for acceptable fluxes for these systems are covered by Specification B 813.

1.4 The following safety hazards caveat pertains only to the test methods portion, Section 15, 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 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.1.1 *ASTM Standards:*

B 32 Specifications for Solder Metal[3]

B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing[4]

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[4]

B 813 Specification for Liquid and Paste Fluxes for Soldering Applications of Copper and Copper Alloy Tube[4]

B 828 Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings[4]

E 2 Method of Preparation of Micrographs of Metals and Alloys[5]

E 3 Methods of Preparation of Metallographic Specimens[6]

E 8 Test Methods for Tension Testing of Metallic Materials[6]

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[6]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[7]

E 53 Methods for Chemical Analysis of Copper[8]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[8]

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)[8]

E 112 Test Methods for Determining Average Grain Size[6]

E 243 Practice for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes[9]

E 527 Practice for Numbering Metals and Alloys (UNS)[10]

2.1.2 *ASME Standards:*

ASME B16.18—Cast copper alloy solder joint pressure fittings[11]

ASME B16.22—Wrought copper and copper alloy solder joint pressure fittings[11]

3. Terminology

3.1 *Definitions:*

3.1.1 *coil*—a length of the product wound into a series of

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[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.

Current edition approved May 10, 1996. Published July 1996. Originally published as B 88 – 32 T. Last previous edition B 88 – 95a.

[2] The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix "C" and a suffix "00." The suffix is permitted to be used to accommodate composition variations of the base alloy.

[3] *Annual Book of ASTM Standards*, Vol 02.04.

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

[5] Discontinued, see *1982 Annual Book of ASTM Standards*, Part 11. Replaced by Practice E 883.

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

[7] *Annual Book of ASTM Standards*, Vol 14.02.

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

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

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

[11] Available from ASME, 345 E. 47th St., New York, NY 10017.

connected turns. The unqualified term "coil" as applied to tube usually refers to a bunched coil.

3.1.1.1 *bunched*—a coil in which the turns are bunched and held together such that the cross section of the bunched turns is approximately circular.

3.1.1.2 *double layer flat*—a coil in which the product is spirally wound into two connected disk-like layers such that one layer is on top of the other. (Sometimes called "double layer pancake coil" or "double layer spirally wound coil.")

3.1.1.3 *level or traverse wound*—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. (Sometimes called "helical coil.")

3.1.1.4 *single layer flat*—a coil in which the product is spirally wound into a single disk-like layer. (Sometimes called "pancake coil" or "single layer spirally wound coil.")

3.1.2 *lengths*—straight pieces of the product.

3.1.2.1 *standard*—uniform lengths recommended in a simplified practice recommendation or established as a commercial standard.

3.1.3 *tube, seamless*—a tube produced with a continuous periphery in all stages of the operations.

3.1.3.1 *tube, copper service*—a bendable copper water tube for underground water service.

3.1.3.2 *tube, copper water*—a seamless copper tube conforming to the particular dimensions commercially known as Copper Water Tube and designated as Types K, L, and M.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *capable of*—as used in this specification, the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Nominal or standard size (Column 1 of Table 1) and whether Type K, L, or M (Sections 3 and 11),

4.1.2 Temper (Sections 5 and 8),

4.1.3 Whether tension tests and grain size determinations are required (Section 8),

4.1.4 Length (see 11.5),

4.1.5 How furnished: straight or coils, and

4.1.6 Quantity (pieces) of each size and type.

4.2 In addition, when material is purchased for agencies of the U.S. Government, it shall conform to the Supplementary Requirements as defined herein when specified in the contract or purchase order.

5. Materials and Manufacture

5.1 The material shall be of such quality and purity that the finished product shall have the properties and characteristics prescribed in this specification, and shall be cold drawn to size.

5.2 The tube shall be finished by such cold-working and annealing operations as are necessary to produce the required temper and surface finish.

5.3 Tube when furnished in coils shall be annealed after coiling.

5.4 Tube when furnished in straight lengths shall normally be in the drawn temper. Annealed straight length tubing is also permitted.

6. Chemical Composition

6.1 The material shall conform to the following chemical requirements for Copper UNS No. C12200:

Copper (incl silver), min, %	99.9
Phosphorus, max, %	0.015–0.040

6.2 These specification limits do not preclude the presence of other elements. Limits for unnamed elements are permitted to be established by agreement between the manufacturer or supplier and the purchaser.

7. Temper

7.1 Seamless copper water tube shall be furnished in the tempers designated below. Current designations as defined in Practice B 601 are shown.

Annealed—O
Drawn—H

8. Mechanical Properties

8.1 The tube shall conform to the mechanical property requirements prescribed in Table 2. Tension tests and grain-size determinations need not be made except when indicated by the purchaser at the time of placing the order. A convenient method of indicating that these tests are to be made is to state that "Test Procedure 'T' is required" (see 4.1.3). Where agreement on the Rockwell hardness tests cannot be reached, the tensile strength and grain-size requirements of Table 2 shall be the basis for acceptance or rejection.

9. Expansion Test

9.1 The annealed (O) tube shall be capable of being expanded in accordance with Test Method B 153 with an expansion of the outside diameter in the following amount:

Nominal or Standard Size, in.	Expansion of Outside Diameter, %
⅝ and under	40
Over ⅝	30

The expanded tube shall show no cracking or rupture visible to the unaided eye.

9.2 As an alternative to the expansion test for tube standard sizes 4 in. and over in the annealed condition, a section 4 in. in length shall be cut from the end of one of the lengths for a flattening test. This 4-in. test specimen shall be flattened so that a gage set at three times the wall thickness will pass over the tube freely throughout the flattened part. The tube so tested shall develop no cracks or flaws visible to the unaided eye as a result of this test. In making the flattening test the elements shall be slowly flattened by one stroke of the press.

10. Nondestructive Testing

10.1 Each tube up to and including 3⅛ in. in outside diameter shall be subjected to an eddy-current test. Testing shall follow the procedures of Practice E 243, except for the determination of "end effect." Tubes shall be passed through an eddy-current test unit adjusted to provide information on the suitability of the tube for the intended application.

10.1.1 Notch-depth standards, rounded to the nearest 0.001 in., shall be 22 % of the wall thickness. The notch-

TABLE 1 Dimensions, Weights, and Tolerances in Diameter and Wall Thickness for Nominal or Standard Copper Water Tube Sizes
(All tolerances are plus and minus except as otherwise indicated)

Nominal or Standard Size, in.	Outside Diameter, in.	Average Outside Diameter[A] Tolerance, in.		Wall Thickness and Tolerances, in.						Theoretical Weight, lb/ft		
				Type K		Type L		Type M				
		Annealed	Drawn	Wall Thickness	Tolerance[B]	Wall Thickness	Tolerance[B]	Wall Thickness	Tolerance[B]	Type K	Type L	Type M
1/4	0.375	0.002	0.001	0.035	0.0035	0.030	0.003	[C]	[C]	0.145	0.126	[C]
3/8	0.500	0.0025	0.001	0.049	0.005	0.035	0.004	0.025	0.002	0.269	0.198	0.145
1/2	0.625	0.0025	0.001	0.049	0.005	0.040	0.004	0.028	0.003	0.344	0.285	0.204
5/8	0.750	0.0025	0.001	0.049	0.005	0.042	0.004	[C]	[C]	0.418	0.362	[C]
3/4	0.875	0.003	0.001	0.065	0.006	0.045	0.004	0.032	0.003	0.641	0.455	0.328
1	1.125	0.0035	0.0015	0.065	0.006	0.050	0.005	0.035	0.004	0.839	0.655	0.465
1 1/4	1.375	0.004	0.0015	0.065	0.006	0.055	0.006	0.042	0.004	1.04	0.884	0.682
1 1/2	1.625	0.0045	0.002	0.072	0.007	0.060	0.006	0.049	0.005	1.36	1.14	0.940
2	2.125	0.005	0.002	0.083	0.008	0.070	0.007	0.058	0.006	2.06	1.75	1.46
2 1/2	2.625	0.005	0.002	0.095	0.010	0.080	0.008	0.065	0.006	2.93	2.48	2.03
3	3.125	0.005	0.002	0.109	0.011	0.090	0.009	0.072	0.007	4.00	3.33	2.68
3 1/2	3.625	0.005	0.002	0.120	0.012	0.100	0.010	0.083	0.008	5.12	4.29	3.58
4	4.125	0.005	0.002	0.134	0.013	0.110	0.011	0.095	0.010	6.51	5.38	4.66
5	5.125	0.005	0.002	0.160	0.016	0.125	0.012	0.109	0.011	9.67	7.61	6.66
6	6.125	0.005	0.002	0.192	0.019	0.140	0.014	0.122	0.012	13.9	10.2	8.92
8	8.125	0.006	+0.002 −0.004	0.271	0.027	0.200	0.020	0.170	0.017	25.9	19.3	16.5
10	10.125	0.008	+0.002 −0.006	0.338	0.034	0.250	0.025	0.212	0.021	40.3	30.1	25.6
12	12.125	0.008	+0.002 −0.006	0.405	0.040	0.280	0.028	0.254	0.025	57.8	40.4	36.7

[A] The average outside diameter of a tube is the average of the maximum and minimum outside diameter, as determined at any one cross section of the tube.
[B] Maximum deviation at any one point.
[C] Indicates that the material is not generally available or that no tolerance has been established.

depth tolerance shall be plus and minus 0.0005 in. Alternatively, at the option of the manufacturer using speed insensitive eddy-current units that are equipped to select a fraction of the maximum unbalance signal, the following percent maximum unbalance signals shall be used:

Nominal or Standard Tube Size, in.	Unbalance Signal Magnitude, max %
Up to 3/8, incl	0.2
1/2 to 2, incl	0.3
Over 2 to 3, incl	0.4

10.1.2 Tubes that do not actuate the signalling device of the eddy-current testers 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 re-examined 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.

10.2 Tube made to this specification shall be capable of withstanding the pressure test of 10.2.1 or 10.2.2. Should subsequent testing by the purchaser establish that the material does not meet these requirements, the material is subject to rejection at the option of the purchaser.

10.2.1 The tube shall stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 6000 psi, calculated from the following equation for thin hollow cylinders under tension:

$$P = 2\,St/(D - 0.8t)$$

where:
P = hydrostatic pressure, psi,
t = wall thickness, in.,
D = outside diameter of the tube, in., and
S = allowable stress of the material, psi.

10.2.2 The tube shall stand an internal air pressure of 60 psig for 5 s without showing evidence of leakage. The test method used shall permit easy visual detection of any leakage, such as by having the tube under water or by the pressure differential method.

11. Dimensions, Weights, and Permissible Variations

11.1 For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the specified limiting

TABLE 2 Mechanical Property Requirements

Temper Designation		Form	Rockwell Hardness[A]		Tensile Strength, min, ksi[B]	Average Grain Size, mm
Standard	Former		Scale	Value		
O60	annealed	coils	F	50 max	30	0.040 min
O50	annealed	straight lengths	F	55 max	30	0.025 min
H58	drawn	drawn	30 T	30 min	36	...

[A] Rockwell hardness tests shall be made on the inside surfaces of the tube. When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values shall be specified subject to agreement between the purchaser and the supplier.
[B] ksi = 1000 psi.

TABLE 3 Roundness Tolerance

t/D (Ratio of Wall Thickness to Outside Diameter)	Roundness Tolerance % of Outside Diameter (Expressed to Nearest 0.001 in.)
0.01 to 0.03, incl	1.5
Over 0.03 to 0.05, incl	1.0
Over 0.05 to 0.10, incl	0.8

TABLE 4 Standard Lengths and Tolerances

Nominal or Standard Size, in.	Type	Standard Length, ft	Tolerance, (all Plus)
Tubes Furnished in Straight Lengths			
Up to 8, incl	K, L, M	20	1 in.
10	L, M	20	1 in.
10	K	18	1 in.
12	M	20	1 in.
12	L	18	1 in.
12	K	12	1 in.
Tubes Furnished in Coils			
Up to 1, incl	K, L	60 and 100	2 ft
1¼ and 1½	K, L	60	2 ft
2	K, L	40 and 45	1 ft

TABLE 5 Sampling Schedule

Number of Pieces in Lot	Number of Sample Pieces to be Taken[A]
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2 % of total number of pieces in the lot but not more than 10 sample pieces

[A] Each sample piece shall be taken from a separate tube.

TABLE 6 Test Methods

Test	ASTM Designation
Chemical Analysis	E 53, E 62
Tension	E 8 (see also 15.2, 15.3 and 15.4).
Rockwell Hardness	E 18
Grain Size	E 2, E 3, E 112 (see also 15.5).
Expansion (Pin Test)	B 153

TABLE 7 Rounding Units

Property	Rounded Unit for Observed or Calculated Value
Chemical Composition, Hardness	nearest unit in the last right-hand place of figures of the specified limit
Tensile Strength	nearest ksi
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

values for any dimensions shall make the tube subject to rejection at the option of the puchaser.

11.2 *Standard Dimensions, Wall Thickness, and Diameter Tolerances*—The standard dimensions, wall thickness and diameter tolerances shall be in accordance with Table 1.

11.3 *Weight*—For purposes of calculating weights, cross-sections, etc., the density of the copper shall be taken as 0.323 lb/in.^{3} The theoretical weight per foot is given in Table 1.

11.4 *Roundness*—For drawn unannealed tube in straight lengths the roundness tolerance shall be as prescribed in Table 2. The deviation from roundness is measured as the difference between major and minor diameters as determined at any one cross section of the tube. No roundness tolerance has been established for annealed tube in straight lengths or for tubes furnished in coils.

11.5 *Lengths and Tolerances:*

11.5.1 *Standard Lengths and Tolerances*—The standard lengths and tolerances shall be as specified in Table 4.

11.5.2 Other lengths and tolerances are permitted to be established by agreement between the manufacturer or supplier and the purchaser.

11.6 *Squareness of Cut*—For tube in straight lengths, the departure from squareness of the end of any tube shall not exceed more than 0.010 in. for tube up to and including ½ in. standard size; and not more than 0.016 in./in. of outside diameter for tube larger than ½ in. standard size.

12. Workmanship, Finish, and Appearance

12.1 The material shall be clean, free of dirt and defects of a nature that interfere with normal commercial applications.

13. Sampling

13.1 Sample pieces shall be selected for test purposes from each lot of 5000 lb or fraction thereof, of each size and type, in accordance with the schedule of Table 5.

14. Number of Tests and Retests

14.1 *Chemical Analysis*—Samples for chemical analysis shall be taken in accordance with Practice E 55. Drillings, millings, etc., shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 13.1 and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

14.1.1 Instead of sampling in accordance with Practice E 55, the manufacturer shall have the option of determining conformance to chemical composition as follows: Conformance shall be determined by the manufacturer by analyzing samples taken at the time the castings are poured or samples taken from the semifinished product. If the manufacturer determines the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product. The number of samples taken for determination of chemical composition shall be as follows:

14.1.1.1 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.

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

14.1.1.3 Due to the discontinuous nature of the processing of castings into wrought products, it is not practical to identify specific casting analysis with a specific quantity of finished material.

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

14.2 *Mechanical Tests*—For the mechanical tests, a specimen shall be taken from each of the sample pieces selected in accordance with 13.1. The required mechanical test shall be made on each of the specimens so selected. The value for the Rockwell hardness number of each specimen shall be established by taking the arithmetical average of at least three readings.

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

14.4 *Retests:*

14.4.1 If any test specimen shows defective machining or develops flaws, it shall be discarded and another specimen substituted.

14.4.2 If the results of any test made to determine the mechanical properties fail to meet the specified requirements, two additional specimens shall be taken from different sample pieces and tested. The results of the tests on both of these specimens shall meet the specified requirements. Failure of more than one specimen to meet the specified requirements for a particular property shall be the cause for rejection of the entire lot.

14.4.3 If the chemical analysis fails to conform to the specified limits, analysis shall be made on a new composite sample prepared from additional pieces selected in accordance with 13.1. The results of this retest shall comply with the specified requirements.

15. Test Methods

15.1 The properties enumerated in this specification shall, in case of disagreement, be determined in accordance with the ASTM methods listed in Table 6.

15.2 Tension test specimens shall be of the full section of the tube and shall conform to the requirements of the section, Specimens for Pipe and Tube, of Test Methods E 8, unless the limitations of the testing machine preclude the use of such a specimen. Test specimens conforming to type No. 1 of Fig. 13, Tension Test Specimens for Large-Diameter Tubular Products, of Test Methods E 8, are permitted to be used when a full section specimen cannot be tested.

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

15.4 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 shall not exceed 100 ksi/min. Above the yield strength, the movement per minute of the testing machine head under load shall not exceed 0.5 in./in. of gage length (or distance between grips for full section specimens).

15.5 The surface of the test specimen for microscopical examination shall approximate a radial longitudinal section of the tube.

16. Significance of Numerical Limits

16.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in Table 7, an observed value 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 afford the inspector representing the purchaser, all reasonable facilities, without charge, to satisfy him that the tubes are being furnished in accordance with the specified requirements.

18. Rejection and Rehearing

18.1 Material that fails to conform to the requirements of this specification is subject to rejection at the option of the purchaser. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer or supplier is permitted to make claim for a rehearing.

19. Packaging and Package Marking

19.1 The material shall be separated by size, composition, and temper, and prepared for shipment in such a manner as to ensure acceptance by common carrier for transportation at the lowest rate applicable and to afford protection from the normal hazards of transportation.

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

19.3 *Product Identification:*

19.3.1 The name or trademark of the manufacturer and the mark indicative of the type shall be permanently (incised) marked on each tube at intervals not greater than 1½ ft. Tube in straight lengths shall be further identified throughout its length by means of a continuous colored stripe, symbol, or logo not less than 3/16 in. in height, including a legend repeated at intervals not greater than 3 ft. The legend shall include the type of the tube, name or trademark of the manufacturer, or both, and the country of origin. Other information is permitted to be included at the option of the manufacturer.

19.3.2 Colors used are: green for Type K, blue for Type L, and red for Type M. Such color marking is not applicable to tube furnished in annealed straight lengths or coils.

20. Keywords

20.1 copper tube; seamless; water tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U. S. Government.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

S1.1.1 *Federal Standards:*[12]

Fed. Std. No. 102 Preservation, Packaging and Packing Levels

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 185 Identification Marking of Copper and Copper-Base Alloy Mill Products

S1.1.2 *Military Standard:*[12]

MIL-STD-129 Marking for Shipment and Storage

S1.1.3 *Military Specification:*[12]

MIL-C-3993 Packaging of Copper and Copper-Base Alloy Mill Products

S2. Quality Assurance

S2.1 *Responsibility for Inspection:*

S2.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer is permitted to use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

S3. Identification Marking

S3.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 185 except that the ASTM specification number and the alloy number shall be used.

S4. Preparation for Delivery

S4.1 *Preservation, Packaging, Packing:*

S4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade or class and shall be preserved and packaged, Level A or C, packed, Level A, B, or C as specified in the contract or purchase order, in accordance with the requirements of MIL-C-3993.

S4.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

[12] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

Designation: B 88M – 96
METRIC

Standard Specification for Seamless Copper Water Tube [Metric][1]

This standard is issued under the fixed designation B 88M; 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. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers Copper UNS No. C12200 seamless copper water tube suitable for general plumbing, and similar applications for the conveyance of fluids, and commonly used with solder, flared, or compression-type fittings. The type of copper water tube suitable for any particular application is determined by the internal or external fluid pressure, by the installation and service conditions, and by local requirements. Means of joining or bending are also factors that affect the selection of the type of tube to be used.[2]

NOTE 1—Annealed tube is suitable for use with flared or compression fittings, and with solder-type fittings, provided rounding and sizing of the tube ends is performed where needed.

NOTE 2—Drawn temper tube is suitable for use with solder-type fittings. Types A and B tube, in the drawn temper, are suitable for use with certain types and sizes of compression fittings.

NOTE 3—This specification is the metric companion of Specification B 88.

1.2 The assembly of copper plumbing or fire sprinkler systems by soldering is described in Practice B 828.

1.3 Solders for joining copper potable water or fire sprinkler systems are covered by Specification B 32. The requirements for acceptable fluxes for these systems are covered by Specification B 813.

1.4 The following safety hazards caveat pertains only to the test methods portion, Section 15, 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 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.1.1 *ASTM Standards:*

B 32 Specifications for Solder Metal[3]
B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing[4]
B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[4]
B 813 Specification for Liquid and Paste Fluxes for Soldering Applications of Copper and Copper Alloy Tube[4]
B 828 Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings[4]
E 2 Method of Preparation of Micrographs of Metals and Alloys[5]
E 3 Methods of Preparation of Metallographic Specimens[6]
E 8 Test Methods for Tension Testing of Metallic Materials[6]
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials[6]
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[7]
E 53 Test Methods for Chemical Analysis of Copper[8]
E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[8]
E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)[8]
E 112 Test Methods for Determining Average Grain Size[6]
E 243 Practice for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes[9]
E 527 Practice for Numbering Metals and Alloys (UNS)[10]

3. Terminology

3.1 *Definitions:*

3.1.1 *coil*—a length of the product wound into a series of connected turns. The unqualified term "coil" as applied to tube usually refers to a bunched coil.

3.1.1.1 *bunched*—a coil in which the turns are bunched and held together such that the cross section of the bunched

[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.

Current edition approved May 10, 1996. Published July 1996. Originally published as B 88M – 83. Last previous edition B 88M – 95.

[2] The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix "C" and a suffix "00." The suffix is permitted to be used to accommodate composition variations of the base alloy.

[3] *Annual Book of ASTM Standards*, Vol 02.04.
[4] *Annual Book of ASTM Standards*, Vol 02.01.
[5] Discontinued, see *1982 Annual Book of ASTM Standards*, Part 11. Replaced by Practice E 883.
[6] *Annual Book of ASTM Standards*, Vol 03.01.
[7] *Annual Book of ASTM Standards*, Vol 14.02.
[8] *Annual Book of ASTM Standards*, Vol 03.05.
[9] *Annual Book of ASTM Standards*, Vol 03.03.
[10] *Annual Book of ASTM Standards*, Vol 01.01.

TABLE 1 Dimensions, Mass, and Tolerances in Diameter and Wall Thickness for Metric Copper Water Tube Sizes
(All tolerances are plus and minus except as otherwise indicated.)

Nominal or Standard Size, mm	Outside Diameter, mm	Average Outside Diameter[A] Tolerance, mm		Wall Thickness and Tolerances, mm						Theoretical Mass,kg/m		
				Type A		Type B		Type C				
		Annealed	Drawn	Wall Thickness	Tolerance[B]	Wall Thickness	Tolerance[B]	Wall Thickness	Tolerance[B]	Type A	Type B	Type C
6	6.0	0.05	0.03	0.80	0.08	0.70	0.07	0.60	[C]	0.117	0.104	0.091
8	8.0	0.05	0.03	0.90	0.09	0.80	0.08	0.60	[C]	0.179	0.162	0.125
10	10.0	0.05	0.03	0.90	0.09	0.80	0.08	0.60	[C]	0.230	0.207	0.158
12	12.0	0.06	0.03	1.2	0.1	0.90	0.09	0.60	0.06	0.364	0.280	0.192
15	15.0	0.06	0.03	1.2	0.1	1.0	0.1	0.70	0.07	0.465	0.393	0.281
18	18.0	0.06	0.03	1.2	0.1	1.0	0.1	0.70	0.07	0.566	0.477	0.340
22	22.0	0.06	0.03	1.6	0.15	1.1	0.1	0.80	0.08	0.917	0.646	0.476
28	28.0	0.07	0.04	1.6	0.15	1.2	0.1	0.90	0.09	1.19	0.903	0.685
35	35.0	0.10	0.04	1.6	0.15	1.4	0.15	1.1	0.1	1.50	1.32	1.05
42	42.0	0.10	0.05	1.8	0.2	1.5	0.15	1.2	0.1	2.03	1.71	1.37
54	54.0	0.10	0.05	2.1	0.2	1.7	0.15	1.5	0.15	3.06	2.50	2.21
67	67.0	0.12	0.05	2.4	0.25	2.0	0.2	1.6	0.15	4.35	3.65	2.94
79	79.0	0.12	0.05	2.8	0.3	2.3	0.25	1.8	0.2	5.99	4.95	3.90
105	105.0	0.12	0.05	3.4	0.35	2.8	0.3	2.4	0.25	9.70	8.04	6.92
130	130.0	0.12	0.05	4.0	0.4	3.1	0.3	2.7	0.25	14.2	11.0	9.65
156	156.0	0.12	0.05	4.8	0.5	3.5	0.35	3.1	0.3	20.3	15.0	13.3
206	206.0	0.15	+0.05 −0.10	6.8	0.7	5.0	0.5	4.3	0.45	38.0	28.2	24.4
257	257.0	0.20	+0.05 −0.15	8.5	0.85	6.3	0.65	5.4	0.55	59.3	44.4	38.2
308	308.0	0.20	+0.05 −0.15	10.3	1.0	7.1	0.7	6.4	0.65	86.1	60.0	54.2

[A] The average outside diameter of a tube is the average of the maximum and minimum outside diameter, as determined at any one cross section of the tube.
[B] Maximum deviation at any one point.
[C] Indicates that the material is not generally available or that no tolerance has been established.

turns is approximately circular.

3.1.1.2 *double layer flat*—a coil in which the product is spirally wound into two connected disk-like layers such that one layer is on top of the other. (Sometimes called "double layer pancake coil" or "double layer spirally wound coil.")

3.1.1.3 *level or traverse wound*—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. (Sometimes called "helical coil.")

3.1.1.4 *single layer flat*—a coil in which the product is spirally wound into a single disk-like layer. (Sometimes called "pancake coil" or "single layer spirally wound coil.")

3.1.2 *lengths*—straight pieces of the product.

3.1.2.1 *standard*—uniform lengths recommended in a simplified practice recommendation or established as a commercial standard.

3.1.3 *tube, seamless*—a tube produced with a continuous periphery in all stages of the operations.

3.1.3.1 *tube, copper service*—a bendable copper water tube for underground water service.

3.1.3.2 *tube, copper water*—a seamless copper tube conforming to the particular dimensions commercially known as Copper Water Tube and designated as Types A, B, and C.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *capable of*—as used in this specification, the test need not be performed by the producer of the material. However, should subsequent testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information:

4.1.1 Nominal or standard size (Column 1 of Table 1) and whether Type A, B, or C (Section 3),

4.1.2 Temper (Section 7),

4.1.3 Whether tension tests and grain size determinations are required (Section 8),

4.1.4 Length (see 11.5),

4.1.5 How furnished: straight or coils,

4.1.6 Quantity (pieces) of each size and type,

4.1.7 Specification number and date, and

4.1.8 In addition, when material is purchased for agencies of the U.S. Government, it shall conform to the Supplementary Requirements as defined herein when specified in the contract or purchase order.

5. Materials and Manufacture

5.1 The material shall be of such quality and purity that the finished product shall have the properties and characteristics prescribed in this specification, and shall be cold-worked to size.

5.2 The tube shall be finished by such cold-working and annealing operations as are necessary to produce the required temper and surface finish.

5.3 Tube when furnished in coils shall be annealed after coiling.

5.4 Tube when furnished in straight lengths shall normally be in the drawn temper. Annealed straight length tubing is also permitted.

6. Chemical Composition

6.1 The material shall conform to the following chemical requirements for Copper UNS No. C12200:

TABLE 2 Mechanical Property Requirements

Temper Designation		Form	Rockwell Hardness[A]		Tensile Strength, min, MPa	Average Grain size, mm
Standard	Former		Scale	Value		
OS060	Annealed	coils	F	50 max	200	0.040 min
OS035	Annealed	straight lengths	F	55 max	200	0.025 min
H58	Drawn	drawn	30 T	30 min	250	...

[A] Rockwell hardness tests shall be made on the inside surfaces of the tube. When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values shall be specified subject to agreement between the purchaser and the supplier.

Copper (incl silver), min, %	99.9
Phosphorus, max, %	0.015–0.040

6.2 These specification limits do not preclude the presence of other elements. Limits for unnamed elements are permitted to be established by agreement between the manufacturer or supplier and the purchaser.

7. Temper

7.1 The copper water tube shall be furnished in the tempers designated below. Current designations as defined in Practice B 601 are as follows:

Annealed-O
Drawn-H

8. Mechanical Properties

8.1 The tube shall conform to the mechanical property requirements prescribed in Table 2. Tension tests and grain-size determinations need not be made except when indicated by the purchaser at the time of placing the order. A convenient method of indicating that these tests are to be made is to state that "Test Procedure T is required" (see 4.1.3). Where agreement on the Rockwell hardness tests cannot be reached, the tensile strength and grain-size requirements of Table 2 shall be the basis for acceptance or rejection.

9. Expansion Test

9.1 The annealed (O) tube shall be capable of being expanded in accordance with Test Method B 153 with an expansion of the outside diameter in the following amount:

Nominal or Standard Size, mm	Expansion of Outside Diameter, %
15 and under	40
Over 15	30

The expanded tube shall show no cracking or rupture visible to the unaided eye.

NOTE 4—The term "unaided eye" as used herein permits the use of corrective spectacles necessary to obtain normal vision.

9.2 As an alternative to the expansion test for tube standard sizes 105 mm and over in the annealed condition, a section 100 mm in length shall be cut from the end of one of the lengths for a flattening test. This 100-mm test specimen shall be flattened so that a gage set at three times the wall thickness will pass over the tube freely throughout the flattened part. The tube so tested shall develop no cracks or flaws visible to the unaided eye as a result of this test. In making the flattening test the elements shall be slowly flattened by one stroke of the press.

10. Nondestructive Testing

10.1 *Eddy-Current Test*—Unless otherwise specified, each tube up to and including 79 mm in outside diameter, or within the capabilities of the eddy-current tester, shall be subjected to an eddy-current test. Testing shall follow the procedure of Practice E 243, except the determination of "end effect" is not required.

10.1.1 The testing of tube of dimensions beyond the capabilities of the eddy-current test apparatus shall be subject to negotiation between the producer and the purchaser.

10.1.2 Notch-depth standards, rounded to the nearest 0.03 mm, shall be 22 % of the wall thickness. The notch-depth tolerance shall be ±0.01 mm. Alternatively, at the option of the manufacturer using speed insensitive eddy-current units that are equipped to select a fraction of the maximum unbalance signal, the following percent maximum unbalance signals shall be used:

Nominal or Standard Tube size, mm	Unbalance Signal Magnitude, max %
Up to and incl 12	0.2
15 to 54, incl	0.3
Over 54 to 79, incl	0.4

10.1.3 Tubes that do not actuate the signalling device of the eddy-current testers 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 the prescribed limits and the tube is suitable for its intended application.

11. Dimensions, Mass, and Permissible Variations

11.1 For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the specified limiting values for any dimensions shall make the tube subject to rejection at the option of the purchaser.

11.2 *Nominal or Standard Dimensions, Wall Thickness, and Diameter Tolerances*—The nominal or standard dimensions, wall thickness, and diameter tolerances shall be in accordance with Table 1.

11.3 *Mass*—For purposes of calculating mass, cross sections, etc., the density of the copper shall be taken as 8.94 g/cm^3. The theoretical mass per metre is shown in Table 1.

11.4 *Roundness*—For drawn unannealed tube in straight lengths the roundness tolerance shall be as prescribed in Table 2. The deviation from roundness is measured as the difference between major and minor diameters as determined at any one cross section of the tube. No roundness tolerance has been established for annealed tube in straight lengths or for tubes furnished in coils.

11.5 *Lengths and Tolerances:*

11.5.1 *Standard Lengths and Tolerances*—The standard lengths and tolerances shall be as specified in Table 4.

11.5.2 Other lengths and tolerances are permitted to be established by agreement between the manufacturer or supplier and the purchaser.

11.6 *Squareness of Cut*—For tube in straight lengths, the departure from squareness of the end of any tube shall not exceed more than 0.25 mm for tube up to and including 15-mm standard size; and not more than 0.40 mm/mm of outside diameter for tube larger than 15-mm standard size.

12. Workmanship, Finish, and Appearance

12.1 The material shall be clean, free of dirt and defects of a nature that interfere with normal commercial applications.

13. Sampling

13.1 Sample pieces shall be selected for test purposes from each lot of 5000 kg or fraction thereof, of each size and type, according to the schedule of Table 5.

TABLE 3 Roundness Tolerance

t/D (Ratio of Wall Thickness to Outside Diameter)	Roundness Tolerance % of Outside Diameter (Expressed to Nearest 0.03 mm)
0.01 to 0.03, incl	1.5
Over 0.03 to 0.05, incl	1.0
Over 0.05 to 0.10, incl	0.8

TABLE 4 Nominal or Standard Lengths and Tolerances

Nominal or Standard Size, mm	Type	Nominal or Standard Length, m	Tolerance, mm (all plus)
Tubes Furnished in Straight Lengths			
Up to 206, incl	A, B, C	6.0	25
257	B, C	6.0	25
257	A	5.5	25
308	C	6.0	25
308	B	5.5	25
308	A	3.6	25
Tubes Furnished in Coils			
Up to 28, incl	A, B	20	600
		30	600
35 and 42	A, B	20	600
54	A, B	12	600
		14	600

TABLE 5 Sampling Schedule

Number of Pieces in Lot	Number of Sample Pieces to be Taken[A]
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2 % of total number of pieces in the lot but not more than 10 sample pieces

[A] Each sample piece shall be taken from a separate tube.

TABLE 6 Test Methods

Test	ASTM Designation
Chemical analysis	E 53, E 62
Tension	E 8 (see also 14.2, 14.3, and 14.4)
Rockwell hardness	E 18
Grain size	E 2, E 3, E 112 (see also 14.5)
Expansion (pin test)	B 153

TABLE 7 Rounding Units

Property	Rounded Unit for Observed or Calculated Value
Chemical composition, Hardness	nearest unit in the last right-hand place of figures of the specified limit
Tensile strength	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

14. Number of Tests and Retests

14.1 *Chemical Analysis*—Samples for chemical analysis shall be taken in accordance with Practice E 55. Drillings, millings, etc., shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 13.1 and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

14.1.1 Instead of sampling in accordance with Practice E 55, the manufacturer shall have the option of determining conformance to chemical composition as follows: Conformance shall be determined by the manufacturer by analyzing samples taken at the time the castings are poured or samples taken from the semifinished product. If the manufacturer determines the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product. The number of samples taken for determination of chemical composition shall be as follows:

14.1.1.1 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.

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

14.1.1.3 Due to the discontinuous nature of the processing of castings into wrought products, it is not practical to identify specific casting analysis with a specific quantity of finished material.

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

14.2 *Mechanical Tests*—For the mechanical tests, a specimen shall be taken from each of the sample pieces selected in accordance with 13.1. The required mechanical test shall be made on each of the specimens so selected. The value for the Rockwell hardness number of each specimen shall be established by taking the arithmetical average of at least three readings.

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

14.4 *Retests:*

14.4.1 If any test specimen shows defective machining or

develops flaws, it shall be discarded and another specimen substituted.

14.4.2 If the results of any test made to determine the mechanical properties fail to meet the specified requirements, two additional specimens shall be taken from different sample pieces and tested. The results of the tests on both of these specimens shall meet the specified requirements.

14.4.3 If the chemical analysis fails to conform to the specified limits, analysis shall be made on a new composite sample prepared from additional pieces selected in accordance with 13.1. The results of this retest shall comply with the specified requirements.

15. Test Methods

15.1 The properties enumerated in this specification shall, in case of disagreement, be determined in accordance with the ASTM methods listed in Table 6.

15.2 Tension test specimens shall be of the full section of the tube and shall conform to the requirements of the section, Specimens for Pipe and Tube, of Test Methods E 8, unless the limitations of the testing machine preclude the use of such a specimen. Test specimens conforming to Type No. 1 of Fig. 13, Tension Test Specimens for Large-Diameter Tubular Products, of Test Methods E 8, are permitted to be used when a full-section specimen cannot be tested.

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

15.4 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 shall not exceed 690 MPa/min. Above the yield strength, the movement per minute of the testing machine head under load shall not exceed 0.5 mm/mm of gage length (or distance between grips for full-section specimens).

15.5 The surface of the test specimen for microscopical examination shall approximate a radial longitudinal section of the tube.

16. Significance of Numerical Limits

16.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in Table 7, an observed value 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 afford the inspector representing the purchaser, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with the specified requirements.

18. Rejection and Rehearing

18.1 Material that fails to conform to the requirements of this specification is subject to rejection at the option of the purchaser. Rejection shall be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer or supplier is permitted to make claim for a rehearing.

19. Packaging and Package Marking

19.1 The material shall be separated by size, composition, and temper, and prepared for shipment in such a manner as to ensure acceptance by common carrier for transportation at the lowest rate applicable and to afford protection from the normal hazards of transportation.

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

19.3 *Product Identification:*

19.3.1 The name or trademark of the manufacturer and the mark indicative of the type shall be permanently (incised) marked on each tube at intervals not greater than 0.5 m. Tube in straight lengths shall be further identified throughout its length by a colored marking of continuous X's, symbol, or logo not less than 4.5 mm in height, including a legend repeated at intervals not greater than 1 m. The legend shall include the type of the tube, name or trademark of the manufacturer, or both, and the country of origin. Other information is permitted to be included at the option of the manufacturer.

19.3.2 Colors used shall be green for Type A, blue for Type B, and red for Type C. Such color marking is not applicable to tube furnished in annealed straight lengths or coils.

20. Keywords

20.1 copper tube; seamless; water tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U.S. Government.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

S1.1.1 *Federal Standards:*[11]

Fed. Std. No. 102 Preservation, Packaging and Packing Levels

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 146A Tolerances for Copper and Copper Base Alloy Mill Products

Fed. Std. No. 185 Identification Marking of Copper and Copper-Base Alloy Mill Products

S1.1.2 *Military Standards:*[11]

MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-129 Marking for Shipment and Storage

S1.1.3 *Military Specification:*[11]

MIL-C-3993 Packaging of Copper and Copper-Base Alloy Mill Products

S2. Quality Assurance

S2.1 *Responsibility for Inspection:*

S2.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer is permitted to use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification when such inspections and tests are deemed necessary to ensure that the material conforms to the prescribed requirements.

S3. Identification Marking

S3.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 185 except that the ASTM specification number and the alloy number shall be used.

S4. Preparation for Delivery

S4.1 *Preservation, Packaging, Packing:*

S4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade, or class and shall be preserved and packaged, Level A or C, packed, Level A, B, or C, as specified in the contract or purchase order, in accordance with the requirements of MIL-C-3393.

S4.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

[11] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

Document Name: ASTM B96: Standard Specification for Copper-Silicon Alloy Plate, Sheet, Strip, and Bolled Bar for General Purposes and Pressure Vessels

CFR Section(s): 46 CFR 119.440

Standards Body: American Society for Testing and Materials

APPROVED

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

Designation: B 96 – 93

Standard Specification for Copper-Silicon Alloy Plate, Sheet, Strip, and Rolled Bar for General Purposes and Pressure Vessels[1]

This standard is issued under the fixed designation B 96; 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. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers copper-silicon alloy plate, sheet, strip, and rolled bar commonly used for drawing, forming, stamping, and bending. The alloys included are C65100, C65400, C65500 and C65800.[2]

1.2 When material is ordered for *ASME Boiler and Pressure Vessel Code* applications, consult the Code[3] for applicable alloys.

NOTE—A complete metric companion to Specification B 96 has been developed—B 96M; therefore, no metric equivalents are presented in this specification.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.1.1 *ASTM Standards:*

B 248 Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar[4]

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[4]

E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes[5]

E 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys[5]

E 118 Test Methods for Chemical Analysis of Copper-Chromium Alloys[5]

E 478 Test Methods for Chemical Analysis of Copper Alloys[5]

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

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Alloy (Section 6),

3.1.2 Temper (Section 7),

3.1.3 Dimensions: Thickness, Width and Length (10.2, 10.3 and 10.4),

3.1.4 Finish (Section 16),

3.1.5 Type of edge, if required: slit, sheared, sawed, square corners, rounded corners, rounded edges or full rounded edges (10.7),

3.1.6 How furnished (straight lengths or coils),

3.1.7 Weight (Section 10.6),

3.1.8 Mill test, if required (Section 21),

3.1.9 Certification, if required (Section 20),

3.1.10 Product identification, if required (Section 22),

3.1.11 Pressure Vessel use, if applicable[3] (1.2, 8.1.1, 10.1, 10.1.1, and 10.6.1),

3.1.12 Specification number and date,

3.1.13 Special tests or exceptions, if any, and

3.1.14 Whether 0.2 % yield strength is required.

3.2 When material is purchased for agencies of the U.S. Government, it shall conform to the Supplementary Requirements as defined in Specification B 248 when specified in the contract or purchase order.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification B 248, unless specifically stated otherwise in this specification.

5. Materials and Manufacture

5.1 Refer to the current edition of Specification B 248.

6. Chemical Composition

6.1 The materials shall conform to the compositions prescribed in Table 1.

6.2 These specification limits do not preclude the presence of other elements. Limits for unnamed elements may be established by agreement between manufacturer or supplier and purchaser.

6.3 Copper may be taken as the difference between the sum of all the elements analyzed and 100 %. When all the elements in Table 1 are analyzed, their sum shall be 99.5 % min.

7. Temper

7.1 Tempers available as described in Practice B 601 are 061, 050, H01, H03, H04, H06, H08, H14 and M20.

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.01 on Plate, Sheet, and Strip.

Current edition approved Mar. 15, 1993. Published May 1993. Originally published as B 96 – 34 T. Last previous edition B 96 – 92a.

[2] The UNS system for copper and copper alloys (see practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix "C" and a suffix "00." The suffix can be used to accommodate composition variations of the base alloy.

[3] For *ASME Boiler and Pressure Vessel Code* applications see related Specification SB-96 in Section 11 of that Code.

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

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

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

TABLE 1 Chemical Requirements

Element	Composition, %		
	Copper Alloy UNS No.		
	C65100	C65400	C65500
Copper, incl silver	remainder	remainder	remainder
Silicon	0.8–2.0[A]	2.7–3.4	2.8–3.8
Manganese	0.7 max	...	0.50–1.3
Tin	...	1.2–1.9	...
Chromium	...	0.01–0.12	...
Zinc, max	1.5	0.5	1.5
Iron, max	0.8	...	0.8
Nickel, max	...	...	0.6
Lead, max	0.05	0.05	0.05

[A] An alloy containing as high as 2.6 % silicon is acceptable providing the sum of all named elements other than copper, silicon, and iron does not exceed 0.3 %.

8. Mechanical Properties

8.1 *Tensile Requirements*—The tension test shall be the standard test for all tempers ofrolled and annealed and hot-rolled materials, and acceptance or rejection based on mechanical properties shall depend only on the tensile properties, which shall conform to the requirements prescribed in Table 2 or Table 3. Tension test specimens shall be taken so the longitudinal axis of the specimen is parallel to the direction of rolling.

8.1.1 For Pressure Vessel Code Applications, the tensile requirements are prescribed in Table 3.

8.1.2 For general purpose applications, the tensile requirements are prescribed in Table 2.

8.2 *Rockwell Hardness*—Since Rockwell hardness tests offer a quick and convenient method of checking copper-silicon alloys of any temper for general conformity to the requirements for tensile strength or grain size, approximate Rockwell hardness values are given in Tables 2 and 3 for general information and assistance in testing.

8.3 *Grain Size*—The grain sizes given in Tables 2 and 3 for annealed tempers are approximate and for information only.

9. Heat Treatment

9.1 Parts fabricated from the rolled tempers of Alloy C65400 may be heat treated at 480°F for 1 h to provide maximum stress relaxation resistance at temperatures up to 220°F. A moderate gain in strength is also realized by this heat treatment. When the material is to be heat treated by the parts fabricator, the supplier shall be consulted for advice on procedures.

10. Dimensions, Weights and Permissible Variations

10.1 Refer to the appropriate paragraphs in Specification B 248 with particular reference to the following tables: (Exceptions for *ASME Pressure Vessel Code* applications are noted).

10.2 *Thickness*—Refer to Table 2.

10.2.1 *Pressure Vessel Code Applications*—The thickness

TABLE 2 Tensile Strength Requirements and Approximate Rockwell Hardness and Grain Size Values

NOTE—Plate is generally available in only the as hot-rolled (M20) temper. Required properties for other tempers shall be agreed upon between the manufacturer and the purchaser at the time of placing the order.

Temper Designation		Tensile Strength, ksi[B]	Approximate Rockwell Hardness		Approximate Grain Size, mm
Standard[A]	Former		F Scale	B Scale	
		Copper Alloy UNS No. C65100			
O61	Annealed	38–45	45–55	...	0.050–0.120
O50	Light anneal	40–50	50–75	...	0.060 max[D]
H01	Quarter-hard	42–52	...	48–63	...
H02	Half-hard	47–57	...	64–73	...
H04	Hard	60–70	...	74–82	...
H06	Extra-hard	67–76	...	78–85	...
H08	Spring	71–79	...	81–86	...
		Copper Alloy UNS Nos. C65500			
O61	Annealed	52–58	70–82	...	0.110 max[D]
O50	Light anneal	55–64	76–93	...	0.055 max[C]
H01	Quarter-hard	60–74	...	65–80	...
H02	Half-hard[C]	72–86	...	79–91	...
H04	Hard[C]	85–99	...	88–96	...
H06	Extra-hard[C]	95–109	...	93–98	...
H08	Spring[C]	102–116	...	94–99	...
M20	Hot-rolled	55–72	72 min	...	...
...	Hot-rolled, cold-rolled finish	58–72	...	60–80	...
	Copper Alloy UNS No. C65400		Superficial 30T	B Scale	
O61	Annealed	65–80	...	...	0.040[D] max
H01	Quarter hard[C]	75–90	64–77	72–91	...
H02	Half hard[C]	86–101	75–79	89–95	...
H03	Three-quarter hard[C]	97–112	77–81	94–97	...
H04	Hard[C]	108–120	80–81	96–98	...
H06	Extra hard[C]	116–126	81–82	97–100	...
H08	Spring[C]	124–133	81–82	99–101	...
H10	Extra spring[C]	131–140	81 min	100–102	...
H14	Super spring[C]	137 min	81 min	101 min	...

[A] Standard designations defined in Practice B 601.
[B] ksi = 1000 psi.
[C] Commercially supplied only as strip. The manufacturer should be consulted where these tempers are desired in sheet or plate.
[D] No minimum grain size requirement is specified, but all annealed material shall be fully recrystallized.

TABLE 3 Tensile Strength Requirements and Approximate Rockwell Hardness and Grain Size Values for Pressure Vessel Applications

Temper Designation		Tensile Strength, ksi[A]	Yield Strength at 0.5% Extension Under Load ksi min	Yield Strength[E] at 0.2% offset, min, ksi	Elongation, min %[C]	Approximate Rockwell F Hardness	Approximate Grain Size, mm
Standard[B]	Former						
			Copper Alloy UNS No. C65500				
O61	Annealed	50–67	18	18	40	70–82	0.110[D]

[A] ksi = 1000 psi.
[B] Standard designations defined in Practice B 601.
[C] Elongation in 2 in.
[D] No minimum grain size requirement is specified, but all annealed material shall be fully recrystallized.
[E] See 3.1.15.

of any place or sheet shall not be more than 0.01 in. under the thickness specified.

10.3 *Width:*

10.3.1 *Slit Metal and Slit Metal with Rolled Edges*—Refer to Table 4.

10.3.2 *Square-Sheared Metal*—Refer to Table 5.

10.3.3 *Sawed Metal*—Refer to Table 6.

10.4 *Length:*

10.4.1 *Schedule of Lengths (Specific and Stock) with Ends*—Refer to Table 7.

10.4.2 *Length Tolerances for Square-Sheared Metal*—Refer to Table 8.

10.4.3 *Length Tolerances for Sawed Metal*—Refer to Table 9.

10.4.4 *Minimum and Maximum Weight of Ends*—Refer to Table 10.

10.5 *Straightness:*

10.5.1 *Slit Metal or Slit Metal Either Straightened or Edge-Rolled*—Refer to Table 11.

10.5.2 *Square-Sheared Metal*—Refer to Table 12.

10.5.3 *Sawed Metal*—Refer to Table 13.

10.6 *Edges:*

10.6.1 *Square Edges*—Refer to Table 14.

10.6.2 *Rounded Corners*—Refer to Table 15.

10.6.3 *Rounded Edges*—Refer to Table 16.

10.6.4 *Full-Rounded Edges*—Refer to Table 17.

10.7 *Weight: Hot-Rolled Sheet and Plate*—Refer to Table 18.

10.7.1 *ASME Pressure Vessel Code Applications*—Refer to Table 4 of this specification.

11. Workmanship, Finish and Appearance

11.1 For workmanship and appearance refer to the current edition of Specification B 248.

11.2 *Finish:* The material is regularly supplied in the following finishes:

11.2.1 *Black*—After hot rolling retains all of the oxides.

11.2.2 *Plain Pickled*—Sulfuric acid pickle only, brick red oxide. Has cuprous and silicon oxides still adherent.

11.2.3 *Specially Cleaned*—Commercially free of all oxides. Has the golden color of the alloy.

11.2.4 *Sand Blasted*—Commercially free of all oxides. Has a dull gray color.

12. Sampling

12.1 Refer to the current edition of Specification B 248.

13. Number of Tests and Retests

13.1 Refer to the current edition of Specification B 248.

14. Specimen Preparation

14.1 Refer to the current edition of Specification B 248 for the preparation of the appropriate test specimen.

15. Test Methods

15.1 The chemical composition shall, in case of disagreement, be determined as follows:

Element	Test Method
Copper	E 478
Silicon	E 54 (Perchloric acid)
Manganese	E 75
Tin	E 478
Chromium	E 118
Zinc	E 478
Iron	E 478
Nickel	E 478
Lead	E 478

15.2 *Mechanical Properties (Tensile, Rockwell and Grain)*—Refer to the appropriate test method in Specification B 248.

16. Significance of Numerical Limits

16.1 Refer to the current edition of Specification B 248.

TABLE 4 Lot Weight Tolerances in Percentage of Theoretical Weight For Pressure Vessel Applications—All Plus

Thickness, in.	Permissible Excess in Average Weight of Lots, Expressed in Percentage of Normal Weight					
	48 in. and Under in Width	Over 48 to 60 in. in Width	Over 60 to 72 in. in Width	Over 72 to 96 in. in Width	Over 96 to 120 in. in Width	Over 120 to 132 in. incl in Width
1/8 to 3/16, incl	6.5	8	9	11	...	...
Over 3/16 to 1/4, incl	6.5	8	9	11	12	...
Over 1/4 to 5/16, incl	6.5	7.75	8.75	11	12	13
Over 5/16 to 3/8, incl	6.25	7.5	8.5	11	12	13
Over 3/8 to 7/16, incl	6	7.25	8.25	11	12	13
Over 7/16 to 1/2, incl	6	7	8	10	11	12
Over 1/2 to 5/8, incl	5.75	6.5	7.5	9	10	11
Over 5/8 to 3/4, incl	5.5	6	7	8	9	10
Over 3/4 to 1, incl	5	5	6.25	7	8	9
Over 1 to 2, incl	3.5	4	5	6	7	8

17. Inspection

17.1 Refer to the current edition of Specification B 248.

18. Rejection and Rehearing

18.1 Refer to the current edition of Specification B 248.

19. Certification

19.1 Refer to the current edition of Specification B 248.

20. Mill Test Report

20.1 Refer to the current edition of Specification B 248.

21. Packaging and Package Marking

21.1 Refer to the current edition of Specification B 248.

22. Supplementary Requirements

22.1 Material purchased for agencies of the U.S. Government shall also conform to the requirements defined in the Supplementary Requirements of Specification B 248.

23. Keywords

23.1 copper-silicon alloy bar; copper-silicon alloy plate; copper-silicon alloy pressure vessels; copper-silicon alloy sheet; copper-silicon alloy strip; UNS C65100; UNS C65400; UNS 65500; UNS C65800

Designation: B 96M – 93a

Standard Specification for Copper-Silicon Alloy Plate, Sheet, Strip, and Rolled Bar for General Purposes and Pressure Vessels [Metric][1]

This standard is issued under the fixed designation B 96M; 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 describes copper-silicon alloy plate, sheet, strip and rolled bar commonly used for drawing, forming, stamping and bending. The alloys included are C65100, C65400, C65500 and C65800.[2]

1.2 Material ordered for *ASME Boiler and Pressure Vessel Code* applications, shall be in the annealed temper of alloy C65500.[3]

NOTE 1—Refer to Practice E 527 for a description of the Unified Numbering System (UNS).

NOTE 2—This specification is the metric companion of Specification B 96.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.1.1 *ASTM Standards:*

B 96 Specification for Copper-Silicon Alloy Plate, Sheet, Strip and Rolled Bar for General Purposes and Pressure Vessels[4]

B 248M Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip and Rolled Bar [Metric][4]

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast[4]

E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes[5]

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

E 118 Test Methods for Chemical Analysis of Copper-Chromium Alloys[5]

E 478 Test Methods for Chemical Analysis of Copper Alloys[5]

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

3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Alloy (Section 6),

3.1.2 Temper (Section 7),

3.1.3 Dimensions: Thickness, Width and Length (Sections 10.2, 10.3 and 10.4),

3.1.4 Type of edge, if required: slit, sheared, sawed, square corners, rounded corners, rounded edges or full rounded edges (Section 10.6),

3.1.5 Finish (Section 16),

3.1.6 How furnished (straight lengths or coils),

3.1.7 Weight (Section 10.7),

3.1.8 Mill Test, if required (Section 21),

3.1.9 Certification, if required (Section 20),

3.1.10 Product identification, if required (Section 22),

3.1.11 Pressure Vessel use if applicable[3] (Sections 1.2, 8.1.1, 10.1 and 10.6.1),

3.1.12 Specification number and date,

3.1.13 Special tests or exceptions, if any,

3.1.14 Whether 0.2 % yield strength is required, and

3.1.15 Whether the metal is to be heat treated to provide maximum stress relaxation resistance (see 9.1).

3.2 When material is purchased for agencies of the U.S. Government, it shall conform to the Supplementary Requirements defined in Specification B 248M when specified in the contract or purchase order.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification B 248M, unless specifically stated otherwise in this specification.

5. Materials and Manufacture

5.1 Refer to the current edition of Specification B 248M.

6. Chemical Composition

6.1 The materials shall conform to the composition prescribed in Table 1.

6.2 These specification limits do not preclude the presence of other elements. Limits for unnamed elements may be established by agreement between manufacturer or supplier and purchaser.

6.3 Copper may be taken as the difference between the sum of all the elements analyzed and 100 %. When all the elements in Table 1 are analyzed, their sum shall be 99.5 % minimum.

[1] This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.01 on Plate, Sheet and Strip.

Current edition approved Aug. 15, 1993. Published October 1993. Originally published as B 96M – 84. Last previous editioin B 96M – 93.

[2] The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix "C" and a suffix "00". The suffix can be used to accommodate composition variations of the base alloy.

[3] For *ASME Boiler and Pressure Vessel Code* applications see related specification SB-96 in Section 11 of that code.

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

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

[6] *Annual Book of ASTM Standards*, Vols 01.01 and 02.01.

TABLE 1 Chemical Requirements

Element	Composition, %			
	Copper Alloy UNS No.			
	C65100	C65400	C65500	C65800
Copper, incl silver	remainder	remainder	remainder	remainder
Silicon	0.6–2.0[A]	2.7–3.4	2.8–3.8	2.8–3.8
Manganese	0.7 max	...	0.50–1.3	0.50–1.3
Tin	...	1.2–1.9	...	...
Chromium	...	0.01–0.12	...	...
Zinc, max	1.5	0.5	1.5	...
Iron, max	0.8	...	0.8	0.25
Nickel, max	...	...	0.6	0.6
Lead, max	0.05	0.05	0.05	...

[A] An alloy containing as high as 2.6 % silicon is acceptable providing the sum of all named elements other than copper, silicon, and iron does not exceed 0.3 %.

7. Temper

7.1 Tempers available as described in Practice B 601 are O61, O50, H01, H03, H04, H06, H08, H14 and M20.

7.2 Plate specified for Boiler and Pressure Vessel Code applications shall be furnished in the annealed O61 temper.

7.3 Plate not specified for Boiler and Pressure Vessel Code applications is generally available in the hot-rolled M20 temper.

8. Mechanical Properties

8.1 *Tensile Requirements*—The tension test shall be the standard test for all tempers of rolled and annealed and hot-rolled materials, and acceptance or rejection based on mechanical properties shall depend only on the tensile properties, which shall conform to the requirements prescribed in Table 2 or Table 3. Tension test specimen shall be taken so the longitudinal axis of the specimen is parallel to the direction of rolling.

8.1.1 *For Pressure Vessel Code Applications*, the tensile requirements are prescribed in Table 3.

8.1.2 For general purpose applications, the tensile requirements are prescribed in Table 2.

8.2 *Rockwell Hardness*—Since Rockwell hardness tests offer a quick and convenient method of checking copper-silicon alloys of any temper for general conformity to the requirements for tensile and strength and grain size, approximate Rockwell hardness values and approximate grain sizes for annealed tempers are given in Tables 2 and 3. This information, therefore, should be considered as being given for general information and assistance in testing only.

9. Heat Treatment

9.1 Parts fabricated from the rolled tempers of Alloy C65400 may be heat treated at 250°C for one h to provide maximum stress relaxation resistance at temperatures up to 105°C. A moderate gain in strength is also realized by this heat treatment. When the material is to be heat treated by the parts fabricator, the supplier shall be consulted for advice on procedure.

10. Dimensions, Weights and Permissible Variations

10.1 Refer to the appropriate paragraphs in Specification

TABLE 2 Tensile Strength Requirements and Approximate Rockwell Hardness and Grain Size Values

Temper Designation		Tensile Strength, MPa	Approximate Rockwell Hardness		Approximate Grain Size, mm
Standard[A]	Former		F Scale	B Scale	
Copper Alloy UNS No. C65100					
O61	Annealed	260–310	45–55	...	0.050–0.120
O50	Light anneal	275–345	50–75	...	0.060 max[B]
H01	Quarter-hard	290–360	...	48–63	...
H02	Half-hard	325–395	...	64–73	...
H04	Hard	415–485	...	74–82	...
H06	Extra-hard	460–525	...	78–85	...
H08	Spring	490–545	...	81–86	...
UNS Nos. C65500 and UNS No. C65800					
O61	Annealed[D]	360–400	70–82	...	0.110[B]
O50	Light anneal	380–440	76–93	...	0.055 max[C]
H01	Quarter-hard	414–510	...	65–80	...
H02	Half-hard[C]	496–593	...	79–91	...
H04	Hard[C]	586–683	...	88–96	...
H06	Extra-hard[C]	655–752	...	93–98	...
H08	Spring[C]	703–800	...	94–99	...
M20	Hot-rolled[E]	380–500	72 min	...	...
...	Hot-rolled, cold-rolled finish	400–500	...	60–80	...
UNS No. C65400			Superficial 30T	B Scale	
O61	Annealed[A]	450–550	...	...	0.040 max[B]
H01	Quarter hard[A]	520–620	64–77	72–91	...
H02	Half hard[A]	590–700	75–79	89–95	...
H03	Three-quarter hard[A]	670–770	77–81	94–97	...
H04	Hard[A]	745–830	80–81	96–98	...
H06	Extra hard[A]	800–870	81–82	97–100	...
H08	Spring[A]	855–920	81–82	99–101	...
H10	Extra spring[A]	900–965	81 min	100–102	...
H14	Super spring[A]	945 min	81 min	101 min	...

[A] Standard designations defined in Practice B 601.
[B] No minimum grain size requirement is specified, but all annealed material shall be fully recrystallized.
[C] Commercially supplied only as strip. The manufacturer should be consulted where these tempers are desired in sheet or plate.
[D] See Section 7.2.
[E] See Section 7.3.

TABLE 3 Tensile Strength Requirements and Approximate Rockwell Hardness and Grain Size Values for Pressure Vessel Applications

Temper Designation		Tensile Strength, MPa	Yield Stength MPa min[B]	Elongation, min %[C]	Approximate Rockwell F Hardness	Approximate Grain Size, mm
Standard[A]	Former					
O61	Annealed	345–460	125	40	72–92	0.110[D]

[A] Standard designations defined in Practice B 601.
[B] Stress corresponding to 0.5 % strain.
[C] Elongation in 2 in. or 50 mm.
[D] No minimum grain size requirement is specified, but all annealed material shall be fully recrystallized.

B 248M with particular reference to the following tables: (Exceptions for ASME Pressure Vessel Code applications are noted).

10.2 *Thickness*—Refer to Table 2.

10.2.1 *For Pressure Vessel Code Applications*—The thickness of any plate or sheet shall not be more than 0.25 mm under the thickness specified.

10.3 *Width:*

10.3.1 *Slit Metal and Slit Metal with Rolled Edges*—Refer to Table 4.

10.3.2 *Square-Sheared Metal*—Refer to Table 5.

10.3.3 *Sawed Metal*—Refer to Table 6.

10.4 *Length:*

10.4.1 *Schedule of Lengths (Specific and Stock) with Ends*—Refer to Table 7.

10.4.2 *Length Tolerances for SquareSheared Metal*—Refer to Table 8.

10.4.3 *Length Tolerances for Sawed Metal*—Refer to Table 9.

10.4.4 *Minimum and Maximum Weight of Ends*—Refer to Table 10.

10.5 *Straightness:*

10.5.1 *Slit Metal or Slit Metal Either Straightened or Edge Rolled*—Refer to Table 11.

10.5.2 *Square-Sheared Metal*—Refer to Table 12.

10.5.3 *Sawed Metal*—Refer to Table 13.

10.6 *Edges:*

10.6.1 *Square Edges*—Refer to Table 14.

10.6.2 *Rounded Corners*—Refer to Table 15.

10.6.3 *Rounded Edges*—Refer to Table 16.

10.6.4 *Full-Rounded Edges*—Refer to Table 17.

10.7 *Weight—Hot-Rolled Sheet and Plate*—Refer to Table 18.

10.7.1 *For ASME Pressure Vessel Code Applications*, refer to Table 4 of this specification.

11. Workmanship and Appearance

11.1 Refer to the current edition of Specification B 248M.

12. Sampling

12.1 Refer to the current edition of Specification B 248M.

13. Number of Tests and Retests

13.1 Refer to the current edition of Specification B 248M.

14. Specimen Preparation

14.1 Refer to the current edition of Specification B 248M for the preparation of the appropriate test specimens.

15. Test Methods

15.1 The chemical composition shall, in case of disagreement, be determined as follows:

Element	Method
Copper	E 478
Silicon	E 54 (Perchloric Acid)
Manganese	E 62
Tin	E 478
Chromium	E 118
Zinc	E 478
Iron	E 478
Nickel	E 478
Lead	E 478

15.2 Mechanical properties (Tensile, Rockwell and Grain Size)—Refer to the appropriate test method in Specification B 248M.

16. Finish

16.1 The material is regularly supplied in the following finishes:

16.1.1 *Black*—After hot rolling retains all of the oxides.

16.1.2 *Plain Pickled*—Sulfuric acid pickle only, brick red oxide. Has cuprous and silicon oxides still adhering.

16.1.3 *Specially Cleaned*—Commercially free of all ox-

TABLE 4 Lot Weight Tolerances in Percentage of Theoretical Weight—All Plus

Thickness (mm)	Permissible Excess in Average Weight of Lots, Expressed in Percentage of Normal Weight					
	1200 mm and Under in Width	Over 1200 to 1500 mm in Width	Over 1500 to 1800 mm in Width	Over 1800 to 2500 mm in Width	Over 2500 to 3000 mm in Width	Over 3000 to 3500 mm incl in Width
3.0 to 5.0, incl	6.5	8	9	11	...	...
Over 5.0 to 6.0, incl	6.5	8	9	11	12	...
Over 6.0 to 8.0, incl	6.5	7.75	8.75	11	12	13
Over 8.0 to 10, incl	6.25	7.5	8.5	11	12	13
Over 10 to 12, incl	6	7	8	10	11	12
Over 12 to 16, incl	5.75	6.5	7.5	9	10	11
Over 16 to 20, incl	5.5	6	7	8	9	10
Over 20 to 25, incl	5	5	6.25	7	8	9
Over 25 to 50, incl	3.5	4	5	6	7	8

ides. Has the golden color of the alloy.

16.1.4 *Sand Blasted*—Commercially free of all oxides. Has a dull dray color.

17. Significance of Numerical Limits

17.1 Refer to the current edition of Specification B 248M.

18. Inspection

18.1 Refer to the current edition of Specification B 248M.

19. Rejection and Rehearing

19.1 Refer to the current edition of Specification B 248M.

20. Certification

20.1 Refer to the current edition of Specification B 248M.

21. Mill Test Report

21.1 Refer to the current edition of Specification B 248M.

22. Packing, Marking, Shipping and Preservation

22.1 Refer to the current edition of Specification B 248M.

23. Supplementary Requirements

23.1 Material purchased for agencies of the U.S. Government shall also conform to the requirements defined in the Supplementary Requirements of Specification B 248M.

24. Keywords

24.1 copper-silicon alloy plate; copper-silicon alloy sheet; copper-silicon alloy strip; copper-silicon alloy rolled bar; copper-silicon alloy pressure vessels; UNS C65100 Flat Products; UNS C65400 Flat Products; UNS C65500 Flat Products; UNS C65800 Flat Products

CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. *HEED THIS NOTICE*: Criminal penalties may apply for noncompliance.

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WASHINGTON, D.C.

Designation: C 150 – 99a

Standard Specification for Portland Cement[1]

This standard is issued under the fixed designation C 150; 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 covers eight types of portland cement, as follows (see Note 1):

1.1.1 *Type I*—For use when the special properties specified for any other type are not required.

1.1.2 *Type IA*—Air-entraining cement for the same uses as Type I, where air-entrainment is desired.

1.1.3 *Type II*—For general use, more especially when moderate sulfate resistance or moderate heat of hydration is desired.

1.1.4 *Type IIA*—Air-entraining cement for the same uses as Type II, where air-entrainment is desired.

1.1.5 *Type III*—For use when high early strength is desired.

1.1.6 *Type IIIA*—Air-entraining cement for the same use as Type III, where air-entrainment is desired.

1.1.7 *Type IV*—For use when a low heat of hydration is desired.

1.1.8 *Type V*—For use when high sulfate resistance is desired.

1.2 When both SI and inch-pound units are present, the SI units are the standard. The inch-pound units are approximations listed for information only.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

C 33 Specification for Concrete Aggregates[2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)[3]

C 114 Test Methods for Chemical Analysis of Hydraulic Cement[3]

C 115 Test Method for Fineness of Portland Cement by the Turbidimeter[3]

C 151 Test Method for Autoclave Expansion of Portland Cement[3]

C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement[3]

C 185 Test Method for Air Content of Hydraulic Cement Mortar[3]

C 186 Test Method for Heat of Hydration of Hydraulic Cement[3]

C 191 Test Method for Time of Setting of Hydraulic Cement by Vicat Needle[3]

C 204 Test Method for Fineness of Hydraulic Cement by Air Permeability Apparatus[3]

C 226 Specification for Air-Entraining Additions for Use in the Manufacture of Air-Entraining Portland Cement[3]

C 266 Test Method for Time of Setting of Hydraulic Cement Paste by Gillmore Needles[3]

C 451 Test Method for Early Stiffening of Hydraulic Cement (Paste Method)[3]

C 452 Test Method for Potential Expansion of Portland Cement Mortars Exposed to Sulfate[3]

C 465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements[3]

C 563 Test Method for Optimum SO_3 in Hydraulic Cement Using 24-h Compressive Strength[3]

C 1038 Test Method for Expansion of Portland Cement Mortar Bars Stored in Water[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *portland cement*—a hydraulic cement produced by pulverizing clinker consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground addition.

3.1.2 *air-entraining portland cement*—a hydraulic cement produced by pulverizing clinker consisting essentially of hydraulic calcium silicates, usually containing one or more of the forms of calcium sulfate as an interground addition, and with which there has been interground an air-entraining addition.

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[1] This specification is under the jurisdiction of ASTM Committee C-1 on Cement and is the direct responsibility of Subcommittee C01.10 on Portland Cement.

Current edition approved Oct. 10, 1999. Published November 1999. Originally published as C 150 – 40 T. Last previous edition C 150 – 99.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

4. Ordering Information

4.1 Orders for material under this specification shall include the following:

4.1.1 This specification number and date,

4.1.2 Type or types allowable. If no type is specified, Type I shall be supplied,

4.1.3 Any optional chemical requirements from Table 2, if desired,

4.1.4 Type of setting-time test required, Vicat or Gillmore. If not specified, the Vicat shall be used,

4.1.5 Any optional physical requirements from Table 3, if desired.

NOTE 1—Cement conforming to the requirements for all types are not carried in stock in some areas. In advance of specifying the use of cement other than Type I, determine whether the proposed type of cement is, or can be made, available.

5. Additions

5.1 The cement covered by this specification shall contain no addition except as follows:

5.1.1 Water or calcium sulfate, or both, if added, shall be in amounts such that the limits shown in Table 1 for sulfur trioxide and loss-on-ignition are not exceeded.

5.1.2 Processing additions used in the manufacture of the cement shall have been shown to meet the requirements of Specification C 465 in the amounts used or greater.

5.1.3 Air-entraining portland cement shall contain an interground addition conforming to the requirements of Specification C 226.

6. Chemical Composition

6.1 Portland cement of each of the eight types shown in Section 1 shall conform to the respective standard chemical requirements prescribed in Table 1. In addition, optional chemical requirements are shown in Table 2.

NOTE 2—When comparing oxide analyses and calculated compounds from different sources or from different historic times, be aware that they may not have been reported on exactly the same basis. Chemical data obtained by Reference and Alternate Test Methods of Test Methods C 114 (wet chemistry) may include titania and phosphorus as alumina unless proper correction has been made (see Test Methods C 114), while data obtained by rapid instrumental methods usually do not. This can result in small differences in the calculated compounds. Such differences are usually within the precision of the analytical methods, even when the methods are properly qualified under the requirements of Test Methods C 114.

7. Physical Properties

7.1 Portland cement of each of the eight types shown in Section 1 shall conform to the respective standard physical requirements prescribed in Table 3. In addition, optional physical requirements are shown in Table 4.

TABLE 1 Standard Chemical Requirements

Cement Type[A]	I and IA	II and IIA	III and IIIA	IV	V
Silicon dioxide (SiO_2), min, %	...	20.0[B,C]	...	...	...
Aluminum oxide (Al_2O_3), max, %	...	6.0	...	...	...
Ferric oxide (Fe_2O_3), max, %	...	6.0[B,C]	...	6.5	...
Magnesium oxide (MgO), max, %	6.0	6.0	6.0	6.0	6.0
Sulfur trioxide (SO_3),[D] max, %					
When $(C_3A)^E$ is 8 % or less	3.0	3.0	3.5	2.3	2.3
When $(C_3A)^E$ is more than 8 %	3.5	[F]	4.5	[F]	[F]
Loss on ignition, max, %	3.0	3.0	3.0	2.5	3.0
Insoluble residue, max, %	0.75	0.75	0.75	0.75	0.75
Tricalcium silicate (C_3S),[E] max, %	...	...	...	35[B]	...
Dicalcium silicate (C_2S),[E] min, %	...	...	...	40[B]	...
Tricalcium aluminate $(C_3A)^E$ max, %	...	8	15	7[B]	5[C]
Tetracalcium aluminoferrite plus twice the tricalcium aluminate[E] $(C_4AF + 2(C_3A))$, or solid solution $(C_4AF + C_2F)$, as applicable, max, %	...	...	...	...	25[C]

[A] See Note 1.

[B] Does not apply when the heat of hydration limit in Table 4 is specified.

[C] Does not apply when the sulfate resistance limit in Table 4 is specified.

[D] There are cases where optimum SO_3 (using Test Method C 563) for a particular cement is close to or in excess of the limit in this specification. In such cases where properties of a cement can be improved by exceeding the SO_3 limits stated in this table, it is permissible to exceed the values in the table, provided it has been demonstrated by Test Method C 1038 that the cement with the increased SO_3 will not develop expansion in water exceeding 0.020 % at 14 days. When the manufacturer supplies cement under this provision, he shall, upon request, supply supporting data to the purchaser.

[E] All values calculated as described in this note shall be rounded according to Practice E 29. When evaluating conformance to a specification, round values to the same number of places as the corresponding table entry before making comparisons. The expressing of chemical limitations by means of calculated assumed compounds does not necessarily mean that the oxides are actually or entirely present as such compounds.

When expressing compounds, C = CaO, S = SiO_2, A = Al_2O_3, F = Fe_2O_3. For example, $C_3A = 3CaO{\cdot}Al_2O_3$.

Titanium dioxide and phosphorus pentoxide (TiO_2 and P_2O_5) shall not be included with the Al_2O_3 content. See Note 2.

When the ratio of percentages of aluminum oxide to ferric oxide is 0.64 or more, the percentages of tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite shall be calculated from the chemical analysis as follows:

Tricalcium silicate = $(4.071 \times \%\ CaO) - (7.600 \times \%\ SiO_2) - (6.718 \times \%\ Al_2O_3) - (1.430 \times \%\ Fe_2O_3) - (2.852 \times \%\ SO_3)$

Dicalcium silicate = $(2.867 \times \%\ SiO_2) - (0.7544 \times \%\ C_3S)$

Tricalcium aluminate = $(2.650 \times \%\ Al_2O_3) - (1.692 \times \%\ Fe_2O_3)$

Tetracalcium aluminoferrite = $3.043 \times \%\ Fe_2O_3$

When the alumina-ferric oxide ratio is less than 0.64, a calcium aluminoferrite solid solution (expressed as $ss(C_4AF + C_2F)$) is formed. Contents of this solid solution and of tricalcium silicate shall be calculated by the following formulas:

$ss(C_4AF + C_2F) = (2.100 \times \%\ Al_2O_3) + (1.702 \times \%\ Fe_2O_3)$

Tricalcium silicate = $(4.071 \times \%\ CaO) - (7.600 \times \%\ SiO_2) - (4.479 \times \%\ Al_2O_3) - (2.859 \times \%\ Fe_2O_3) - (2.852 \times \%\ SO_3)$.

No tricalcium aluminate will be present in cements of this composition. Dicalcium silicate shall be calculated as previously shown.

[F] Not applicable.

TABLE 2 Optional Chemical Requirements[A]

Cement Type	I and IA	II and IIA	III and IIIA	IV	V	Remarks
Tricalcium aluminate (C_3A),[B] max, %	...	...	8	...	...	for moderate sulfate resistance
Tricalcium aluminate (C_3A),[B] max, %	...	...	5	...	...	for high sulfate resistance
Sum of tricalcium silicate and tricalcium aluminate,[B] max, %	...	58[C]	...	...	...	for moderate heat of hydration
Equivalent Alkalies ($Na_2O + 0.658K_2O$), max, %	0.60[D]	0.60[D]	0.60[D]	0.60[D]	0.60[D]	low-alkali cement

[A] These optional requirements apply only when specifically requested. Verify availability before ordering. See Note 1 in Section 4.

[B] All values calculated as described in this note shall be rounded according to Practice E 29. When evaluating conformance to a specification, round values to the same number of places as the corresponding table entry before making comparisons. The expressing of chemical limitations by means of calculated assumed compounds does not necessarily mean that the oxides are actually or entirely present as such compounds.

When expressing compounds, $C = CaO$, $S = SiO_2$, $A = Al_2O_3$, $F = Fe_2O_3$. For example, $C_3A = 3CaO{\cdot}Al_2O_3$.

Titanium dioxide and phosphorus pentoxide (TiO_2 and P_2O_5) shall not be included with the Al_2O_3 content. See Note 2.

When the ratio of percentages of aluminum oxide to ferric oxide is 0.64 or more, the percentages of tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite shall be calculated from the chemical analysis as follows:

Tricalcium silicate = $(4.071 \times \%\ CaO) - (7.600 \times \%\ SiO_2) - (6.718 \times \%\ Al_2O_3) - (1.430 \times \%\ Fe_2O_3) - (2.852 \times \%\ SO_3)$

Dicalcium silicate = $(2.867 \times \%\ SiO_2) - (0.7544 \times \%\ C_3S)$

Tricalcium aluminate = $(2.650 \times \%\ Al_2O_3) - (1.692 \times \%\ Fe_2O_3)$

Tetracalcium aluminoferrite = $3.043 \times \%\ Fe_2O_3$

When the alumina-ferric oxide ratio is less than 0.64, a calcium aluminoferrite solid solution (expressed as ss ($C_4AF + C_2F$)) is formed. Contents of this solid solution and of tricalcium silicate shall be calculated by the following formulas:

$ss(C_4AF + C_2F) = (2.100 \times \%\ Al_2O_3) + (1.702 \times \%\ Fe_2O_3)$

Tricalcium silicate = $(4.071 \times \%\ CaO) - (7.600 \times \%\ SiO_2) - (4.479 \times \%\ Al_2O_3) - (2.859 \times \%\ Fe_2O_3) - (2.852 \times \%\ SO_3)$.

No tricalcium aluminate will be present in cements of this composition. Dicalcium silicate shall be calculated as previously shown.

[C] The optional limit for heat of hydration in Table 4 shall not be requested when this optional limit is requested.

[D] Specify this limit when the cement is to be used in concrete with aggregates that are potentially reactive and no other provisions have been made to protect the concrete from deleteriously reactive aggregates. Refer to Specification C 33 for information on potential reactivity of aggregates.

TABLE 3 Standard Physical Requirements

Cement Type[A]	I	IA	II	IIA	III	IIIA	IV	V
Air content of mortar,[B] volume %:								
max	12	22	12	22	12	22	12	12
min	...	16	...	16	...	16	...	...
Fineness,[C] specific surface, m^2/kg (alternative methods):								
Turbidimeter test, min	160	160	160	160	...	...	160	160
Air permeability test, min	280	280	280	280	...	...	280	280
Autoclave expansion, max, %	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Strength, not less than the values shown for the ages indicated as follows:[D]								
Compressive strength, MPa (psi):								
1 day	...	...	...	...	12.0 (1740)	10.0 (1450)	...	...
3 days	12.0 (1740)	10.0 (1450)	10.0 (1450) 7.0[E] (1020)[E]	8.0 (1160) 6.0[E] (870)[E]	24.0 (3480)	19.0 (2760)	...	8.0 (1160)
7 days	19.0 (2760)	16.0 (2320)	17.0 (2470) 12.0[E] (1740)[E]	14.0 (2030) 9.0[E] (1310)[E]	...	...	7.0 (1020)	15.0 (2180)
28 days	...	...	...	...	...	...	17.0 (2470)	21.0 (3050)
Time of setting (alternative methods):[F]								
Gillmore test:								
Initial set, min, not less than	60	60	60	60	60	60	60	60
Final set, min, not more than	600	600	600	600	600	600	600	600
Vicat test:[G]								
Time of setting, min, not less than	45	45	45	45	45	45	45	45
Time of setting, min, not more than	375	375	375	375	375	375	375	375

[A] See Note 1.

[B] Compliance with the requirements of this specification does not necessarily ensure that the desired air content will be obtained in concrete.

[C] The testing laboratory shall select the fineness method to be used. However, when the sample fails to meet the requirements of the air-permeability test, the turbidimeter test shall be used, and the requirements in this table for the turbidimetric method shall govern.

[D] The strength at any specified test age shall be not less than that attained at any previous specified test age.

[E] When the optional heat of hydration or the chemical limit on the sum of the tricalcium silicate and tricalcium aluminate is specified.

[F] The time-of-setting test required shall be specified by the purchaser. In case he does not so specify, the requirements of the Vicat test only shall govern.

[G] The time of setting is that described as initial setting time in Test Method C 191.

TABLE 4 Optional Physical Requirements[A]

Cement Type[A]	I	IA	II	IIA	III	IIIA	IV	V
False set, final penetration, min, %	50	50	50	50	50	50	50	50
Heat of hydration:								
7 days, max, kJ/kg (cal/g)	...	...	290 (70)[B]	290 (70)[B]	...	...	250 (60)[C]	...
28 days, max, kJ/kg (cal/g)	...	...	...	...	...	...	290 (70)[C]	...
Strength, not less than the values shown:								
Compressive strength, MPa (psi)								
28 days	28.0 (4060)	22.0 (3190)	28.0 (4060) 22.0[B] (3190)[B]	22.0 (3190) 18.0[B] (2610)[B]	...	...	...	...
Sulfate resistance,[D] 14 days, max, % expansion	...	...	...[E]	...[E]	...	...	...	0.040

[A] These optional requirements apply only when specifically requested. Verify availability before ordering. See Note 1 in Section 4.

[B] The optional limit for the sum of the tricalcium silicate and tricalcium aluminate in Table 2 shall not be requested when this optional limit is requested. These strength requirements apply when either heat of hydration or the sum of tricalcium silicate and tricalcium aluminate requirements are requested.

[C] When the heat of hydration limit is specified, it shall be instead of the limits of C3S, C2S, C3A, SiO_2, and Fe_2O_3 listed in Table 1.

[D] When the sulfate resistance is specified, it shall be instead of the limits of C_3A, $C_4AF + 2\ C_3A$, SiO_2, and Fe_2O_3 listed in Table 1.

[E] Cement meeting the high sulfate resistance limit for Type V are deemed to meet the moderate sulfate resistance requirement of Type II.

8. Sampling

8.1 When the purchaser desires that the cement be sampled and tested to verify compliance with this specification, perform sampling and testing in accordance with Practice C 183.

8.2 Practice C 183 is not designed for manufacturing quality control and is not required for manufacturer's certification.

9. Test Methods

9.1 Determine the applicable properties enumerated in this specification in accordance with the following test methods:

9.1.1 *Air Content of Mortar*—Test Method C 185.

9.1.2 *Chemical Analysis*—Test Methods C 114.

9.1.3 *Strength*—Test Method C 109.

9.1.4 *False Set*—Test Method C 451.

9.1.5 *Fineness by Air Permeability*—Test Method C 204.

9.1.6 *Fineness by Turbidimeter*—Test Method C 115.

9.1.7 *Heat of Hydration*—Test Method C 186.

9.1.8 *Autoclave Expansion*—Test Method C 151.

9.1.9 *Time of Setting by Gillmore Needles*—Test Method C 266.

9.1.10 *Time of Setting by Vicat Needles*—Test Method C 191.

9.1.11 *Sulfate Resistance*—Test Method C 452 (sulfate expansion).

9.1.12 *Calcium Sulfate (expansion of) Mortar*—Test Method C 1038.

9.1.13 *Optimum SO_3*—Test Method C 563.

10. Inspection

10.1 Inspection of the material shall be made as agreed upon between the purchaser and the seller as part of the purchase contract.

11. Rejection

11.1 The cement shall be rejected if it fails to meet any of the requirements of this specification.

11.2 At the option of the purchaser, retest, before using, cement remaining in bulk storage for more than 6 months or cement in bags in local storage in the custody of a vendor for more than 3 months after completion of tests and reject the cement if it fails to conform to any of the requirements of this specification. Cement so rejected shall be the responsibility of the owner of record at the time of resampling for retest.

11.3 Packages shall identify the mass contained as net weight. At the option of the purchaser, packages more than 2 % below the mass marked thereon shall be rejected and if the average mass of packages in any shipment, as shown by determining the mass of 50 packages selected at random, is less than that marked on the packages, the entire shipment shall be rejected.

12. Manufacturer's Statement

12.1 At the request of the purchaser, the manufacturer shall state in writing the nature, amount, and identity of any air-entraining addition and of any processing addition used, and also, if requested, shall supply test data showing compliance of such air-entraining addition with Specification C 226 and of such processing addition with Specification C 465.

13. Packaging and Package Marking

13.1 When the cement is delivered in packages, the words "Portland Cement," the type of cement, the name and brand of the manufacturer, and the mass of the cement contained therein shall be plainly marked on each package. When the cement is an air-entraining type, the words "air-entraining" shall be plainly marked on each package. Similar information shall be provided in the shipping documents accompanying the shipment of packaged or bulk cement. All packages shall be in good condition at the time of inspection.

NOTE 3—With the change to SI units, it is desirable to establish a standard SI package for portland cements. To that end 42 kg (92.59 lb) provides a convenient, even-numbered mass reasonably similar to the traditional 94-lb (42.6384-kg) package.

14. Storage

14.1 The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building that will protect the cement from dampness and minimize warehouse set.

15. Manufacturer's Certification

15.1 Upon request of the purchaser in the contract or order, a manufacturer's report shall be furnished at the time of shipment stating the results of tests made on samples of the material taken during production or transfer and certifying that the cement conforms to applicable requirements of this specification.

16. Keywords

16.1 hydraulic cement; portland cement; specification