Designation: B543/B543M – 18

Standard Specification for Welded Copper and Copper-Alloy Heat Exchanger Tube[1]

This standard is issued under the fixed designation B543/B543M; 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 welded tube of copper and various copper alloys up to 3⅛ in., inclusive, in diameter, for use in surface condensers, evaporators, heat exchangers, and general engineering applications. The following coppers or copper alloys are involved:[2]

Copper or Copper Alloy UNS No.[2]	Previously Used Designation	Type of Metal
C10800[A]	...	oxygen-free, low phosphorus
C12200[A]	...	DHP phosphorized, high residual phosphorus
C19400	...	copper-iron alloy
C23000	...	red brass
C44300	...	arsenical admiralty
C44400	...	antimonial admiralty
C44500	...	phosphorized admiralty
C68700	...	arsenical aluminum brass
C70400	...	95-5 copper-nickel
C70600	...	90-10 copper-nickel
C70620	...	90-10 copper-nickel (Modified for Welding)
C71000	...	80-20 copper-nickel
C71500	...	70-30 copper-nickel
C71520	...	70-30 copper-nickel (Modified for Welding)
C71640	...	copper-nickel-iron-manganese
C72200	...	...

[A] Copper UNS Nos. C10800 and C12200 are classified in Classification B224.

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

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* (**Warning—**Mercury has been designated by many regulatory agencies as a hazardous substance that can cause serious medical issues. Mercury, or its vapor, has been demonstrated to be hazardous to health and corrosive to materials. Use caution when handling mercury and mercury-containing products. See the applicable product Safety Data Sheet (SDS) for additional information. The potential exists that selling mercury or mercury-containing products, or both, is prohibited by local or national law. Users must determine legality of sales in their location.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

B153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing

B154 Test Method for Mercurous Nitrate Test for Copper Alloys

B224 Classification of Coppers

B846 Terminology for Copper and Copper Alloys

B858 Test Method for Ammonia Vapor Test for Determining Susceptibility to Stress Corrosion Cracking in Copper Alloys

B900 Practice for Packaging of Copper and Copper Alloy Mill Products for U.S. Government Agencies

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

E3 Guide for Preparation of Metallographic Specimens

E8/E8M Test Methods for Tension Testing of Metallic Materials

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E53 Test Method for Determination of Copper in Unalloyed

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

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[2] New designation established in accordance with Practice E527. In the new UNS system, the designations for copper alloys are simply expansions of the present standard designations by a prefix "C" and a suffix "00."

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

Copper by Gravimetry
E54 Test Methods for Chemical Analysis of Special Brasses and Bronzes (Withdrawn 2002)[4]
E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)[4]
E112 Test Methods for Determining Average Grain Size
E118 Test Methods for Chemical Analysis of Copper-Chromium Alloys (Withdrawn 2010)[4]
E243 Practice for Electromagnetic (Eddy Current) Examination of Copper and Copper-Alloy Tubes
E255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition
E478 Test Methods for Chemical Analysis of Copper Alloys
E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *ASME Standard:*[5]
ASME Boiler and Pressure Vessel Code

3. Terminology

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

4. Types of Welded Tube

4.1 *Forge-Welded Tube* manufactured as described in 6.2.2.1, 6.2.2.2, and 6.2.2.3.

4.1.1 *As-Welded Tube*—Forge-welded tube with internal and external flash removed and no further refinement of grain structure.

4.1.2 *Welded and Annealed Tube*—Forge-welded tube with internal and external flash removed, that has been annealed to produce a uniform grain size appropriate to the specified annealed temper.

4.1.3 *Welded and Cold-Reduced Tube*—Forge-welded tube with internal and external flash removed and subsequently cold-reduced to conform to the specified size and temper.

4.1.4 *Welded and Cold-Drawn Tube*—Forge-welded tube with internal and external flash removed and subsequently cold-drawn over a plug or mandrel to the specified size and temper.

4.2 *Fusion-Welded Tube* manufactured as described in section 6.3.

4.2.1 *As-Welded Tube*—Fusion-welded tube with no further refinement of grain structure.

4.2.2 *Welded and Annealed Tube*—Fusion-welded tube that has been annealed to produce a uniform grain size appropriate to the specified annealed temper. The structure of the weld zone shall be that which is typical of a fusion weld.

4.2.3 *Welded and Cold-Reduced Tube*—Fusion-welded tube subsequently cold-reduced to conform to the specified size and temper.

4.2.4 *Welded and Cold-Drawn Tube*—Fusion-welded tube subsequently cold-drawn over a plug or mandrel to the specified size and temper.

4.3 *Fully Finished Tube*—Welded tube with internal and external flash removed, if present, and subsequently cold-drawn over a plug or mandrel and annealed, and redrawn when necessary to conform to the specified temper.

5. Ordering Information

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

5.1.1 ASTM designation and year of issue;

5.1.2 Copper or Copper Alloy UNS No. designation (for example, UNS No. C10800);

5.1.3 Tube type (Section 4);

5.1.4 Temper (Section 8);

5.1.5 Dimensions, the diameter, wall thickness, whether minimum or nominal wall, and length, (Section 14); and

5.1.6 Quantity of each size (number of pieces and length, in inches or feet and inches);

5.2 The following options are available but may not be included unless specified at the time of placing of the order, when required:

5.2.1 When heat identification or traceability details;

5.2.2 Whether a pressure test is to be used instead of the eddy-current test (Section 13.1);

5.2.3 Whether cut ends of the tube are to be deburred, chamfered, or otherwise treated (Section 15);

5.2.4 If the product is to be subsequently welded, (see Table 1, Footnote F);

5.2.5 Certification, if required (Section 23); and

5.2.6 Mill test report, if required (Section 24).

5.3 If product is purchased for agencies of the U.S. Government (see the Supplementary Requirements section of {this specification or the general requirements section} for additional requirements, if specified), and

5.3.1 If product is ordered for *ASME Boiler and Pressure Vessel Code* application (see Certification Section 23).

6. Materials and Manufacture

6.1 *Materials:*

6.1.1 The material of manufacture shall be strip of one of the Copper Alloy UNS Nos. listed in section 1.1 of such purity and soundness as to be suitable for processing into the products prescribed herein.

6.1.2 When specified in the contract or purchase order that heat identification or traceability is required, the purchaser shall specify the details desired.

6.2 *Manufacture:*

6.2.1 The product shall be manufactured by forming the material into a tubular shape on a suitable forming mill.

6.2.2 Welding shall be accomplished by any process that produces a forge weld leaving no crevice in the weld seam visible to the unaided eye.

6.2.2.1 *Forge-Welded Tube*—The edges of the strip shall be heated to the required welding temperature, usually by high frequency electric current, and be pressed firmly together causing a forge-type joint to be formed with internal and external flash or bead.

6.2.2.2 The external flash (that portion of the weld which extends beyond the normal wall) shall always be removed.

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

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

TABLE 1 Chemical Requirements

Copper or Copper Alloy UNS No.	Composition, %											
	Copper[A]	Nickel incl Cobalt	Lead, max	Iron	Zinc	Manganese	Aluminum	Phosphorus	Tin	Antimony	Arsenic	Other Elements
C10800	99.95[A, B] min	...	...	...	...	...	...	0.005–0.012	...	...	...	...
C12200	99.9[A] min	...	...	...	...	...	...	0.015–0.040	...	...	...	...
C19400	97.0 min	...	0.03	2.1–2.6	0.05–0.20	...	...	0.015–0.15	...	...	...	...
C23000	84.0–86.0[C, D]	...	0.05	0.05 max	remainder	...	...	...	...	...	...	...
C44300	70.0–73.0	...	0.07	0.06 max	remainder	...	...	...	0.8–1.2[E]	...	0.02–0.06	...
C44400	70.0–73.0	...	0.07	0.06 max	remainder	...	...	...	0.8–1.2[E]	0.02–0.10	...	...
C44500	70.0–73.0	...	0.07	0.06 max	remainder	...	...	0.02–0.10	0.8–1.2[E]	...	...	...
C68700	76.0–79.0[A, F]	...	0.07	0.06 max	remainder	...	1.8–2.5	...	...	...	0.02–0.06	...
C70400	remainder[A, F]	4.8–6.2	0.05	1.3–1.7	1.0 max	0.30–0.8	...	...	...	...	...	...
C70600	remainder[A, F]	9.0–11.0	0.05	1.0–1.8	1.0 max	1.0 max	...	...	...	...	...	...
C70620	86.5 min[A, F]	9.0–11.0	0.02	1.0–1.8	0.50 max	1.0	...	0.02 max	...	...	...	C 0.05 max S 0.02 max
C71000	remainder[A, F, G]	19.0–23.0	0.05	0.50–1.0	1.0 max[G]	1.0 max	...	[G]	...	...	...	[G]
C71500	remainder[A, F]	29.0–33.0	0.05	0.40–1.0	1.0 max	1.0 max	...		...	...	...	...
C71520	65.0 min[A, F]	29.0–33.0	0.02	0.40–1.0	0.50 max	1.0 max	...	0.02 max	...	...	...	C 0.05 max S 0.02 max
C71640	remainder[A, F, G]	29.0–32.0	0.05[G]	1.7–2.3	1.0 max[G]	1.5–2.5	...	[G]	...	...	...	C 0.06[G] max S 0.03 max
C72200	remainder[A, C, G, H]	15.0–18.0	0.05[G]	0.50–1.0	1.0 max[G]	1.0 max	...	[G]	...	...	...	[G] Si 0.03 max Ti 0.03 max[H]

[A] Cu value includes Ag.
[B] Copper + silver + phosphorus.
[C] Cu + Sum of Named Elements, 99.8 % min.
[D] Not including Ag.
[E] For tubular products, the minimum Sn content may be 0.9 %
[F] Cu + Sum of Named Elements, 99.5 % min.
[G] When the product is for subsequent welding applications and so specified by the purchaser, zinc shall be 0.50 % max, lead 0.02 % max, phosphorus 0.02 % max, sulfur 0.02 % max, and carbon 0.05 % max.
[H] Chromium 0.30 to 0.7.

6.2.2.3 The internal flash shall be removed to the extent that it shall not exceed 0.006 in. [0.152 mm] in height or 10 % of the nominal wall thickness, whichever is greater.

6.3 *Fusion-Welded Tube*—The edges of the strip shall be brought together and welded, usually by a GTAW welding process, without the addition of filler metal, causing a fusion-type joint to be formed with no internal or external flash or bead removal necessary.

6.4 *Fully Finished Tube*—May be welded and subsequently processed by any method that would produce a tube suitable for subsequent cold-drawing and annealing.

6.5 There shall be no crevice in the weld seam visible to the unaided eye.

7. Chemical Composition

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

7.2 The composition limits do not preclude the presence of other elements. By agreement between the manufacturer and purchaser, limits may be established and analysis required for unnamed elements.

7.3 For copper alloys in which copper is specified as the remainder, copper may be taken as the difference between the sum of all the elements analyzed and 100 %.

7.3.1 *Copper Alloy UNS Nos. C70400, C70600, C70620, C71000, C71500, and C71640*—When all the elements in Table 1 are analyzed, their sum shall be 99.5 % minimum.

7.3.2 *Copper Alloy UNS No. C72200*—When all the elements in Table 1 are analyzed, their sum shall be 99.8 % minimum.

7.4 For copper alloys in which zinc is specified as the remainder, either copper or zinc may be taken as the difference between the sum of all the elements analyzed and 100 %.

7.4.1 *Copper Alloy UNS No. C23000*—When all the elements in Table 1 are analyzed, their sum shall be 99.8 % minimum.

7.4.2 *Copper Alloy UNS Nos. C44300, C44400, and C44500*—When all the elements in Table 1 are analyzed, their sum shall be 99.6 % minimum.

7.4.3 *Copper Alloy UNS No. C68700*—When all the elements in Table 1 are analyzed, their sum shall be 99.5 % minimum.

8. Temper

8.1 Tube tempers shall be designated as follows:

8.1.1 Welded and annealed WO61.

8.1.1.1 Welded and light cold worked WC55.

8.2 Other tempers shall be produced to the mechanical properties as agreed upon between the manufacturer or supplier and the purchaser.

8.3 Tubes of Copper Alloy UNS Nos. C23000, C44300, C44400, C44500, and C68700 shall be furnished in the annealed temper or the stress-relieved condition as specified in the purchase order unless otherwise agreed upon between the purchaser and the manufacturer or supplier.

8.4 Tubes of Copper Alloy UNS Nos. C12200, C19400, C70400, C70600, C70620, C71000, C71500, C71520, C71640, and C72200 are normally supplied in the temper specified in the purchase order without stress-relief treatment.

NOTE 1—Some tubes, when subjected to aggressive environments, may be subject to stress-corrosion cracking failure because of the residual tensile stresses developed in straightening. For such applications, it is suggested that tubes of Copper Alloy UNS Nos. C23000, C44300, C44400, C44500, and C68700 be subjected to a stress-relieving thermal treatment subsequent to straightening. If required, this must be specified on the purchase order or contract. Tolerances for roundness and length, and the condition of straightness, for tube so ordered, shall be to the requirements agreed upon between the manufacturer and the purchaser.

9. Grain Size for Annealed Tempers

9.1 Samples of annealed temper tubes shall be examined at a magnification of 75 diameters. The grain size shall be determined in the wall beneath the internal enhancement. While there is not grain size range, the microstructure shall show complete recrystallization and the weld zone shall have a structure typical of hot-forged welds.

10. Mechanical Property Requirements

10.1 *Tensile Strength and Yield Strength Requirements:*

10.2 Product furnished under this specification shall conform to the tensile and yield strength requirements prescribed in Table 2 or Table 3 when tested in accordance with Test Methods E8/E8M.

10.2.1 Acceptance or rejection based upon mechanical properties shall depend only on tensile strength and yield strength.

11. Performance Requirements

11.1 *Expansion Test Requirements:*

11.1.1 Product in the annealed tempers and the light cold-worked temper shall withstand expansion in accordance with Test Method B153 to the degree specified in Table 4.

11.1.2 The expanded tube area shall be free of defects, but blemishes of a nature that do not interfere with the intended application are acceptable.

11.2 *Flattening Test:*

11.2.1 The flattening test shall be performed in accordance with the Test Method section in B968/B968M.

11.3 *Reverse Bend Test:*

11.3.1 When specified in the contract or purchase order, the reverse bend test described in 19.2.8 of the Test Methods section shall be performed.

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

12. Other Requirements

12.1 *Mercurous Nitrate Test or Ammonia Vapor Test:*

12.1.1 The mercurous nitrate or ammonia vapor test is required only for Copper Alloys UNS Nos. C23000; C44300;

TABLE 2 Tensile Requirements—Inch-Pound Values

NOTE 1—See Table 3 for tensile requirements—SI values.

Copper or Copper Alloy UNS No.	Temper		Tensile Strength, min, ksi[A]	Yield Strength at 0.5 % Extension Under Load, min, ksi[A]
	Designation	Name		
C10800, C12200	W061	annealed	30	9[B]
	WC55	light cold-worked	32	15
C19400	W061	annealed	45	15
	WC55	light cold-worked	45	22
C23000	W061	annealed	40	12
	WC55	light cold-worked	42	20
C44300, C44400, C44500	W061	annealed	45	15
	WC55	light cold-worked	50	35
C68700	W061	annealed	50	18
	WC55	light cold-worked	[C]	[C]
C70400	W061	annealed	38	12
	WC55	light cold-worked	40	30
C70600	W061	annealed	40	15
	WC55	light cold-worked	45	35
C70620	WO61	annealed	40	15
	WC55	light cold-worked	45	35
C71000	W061	annealed	45	16
	WC55	light cold-worked	50	35
C71500	W061	annealed	52	18
	WC55	light cold-worked	54	35
C71520	WO61	annealed	52	18
	WC55	light cold-worked	54	35
C71640	W061	annealed	63	25
	WC55	light cold-worked	75	40
C72200	W061	annealed	45	16
	WC55	light cold-worked	50	30

[A] ksi = 1000 psi.
[B] Light straightening operation is permitted.
[C] Where no properties are shown, strength requirements shall be as agreed upon between the purchaser and the manufacturer or supplier.

TABLE 3 Tensile Requirements—SI Values

NOTE 1—See Table 2 for tensile requirements—inch-pound values.

Copper or Copper Alloy UNS No.	Temper		Tensile Strength, min, MPA	Yield Strength at 0.5 % Extension Under Load, min, MPA
	Designation	Name		
C10800, C12200	W061	annealed	205	60[A]
	WC55	light cold-worked	220	105
C19400	W061	annealed	310	105
	WC55	light cold-worked	310	150
C23000	W061	annealed	275	85
	WC55	light cold-worked	290	140
C44300, C44400, C44500	W061	annealed	310	105
	WC55	light cold-worked	345	240
C68700	W061	annealed	345	125
	WC55	light cold-worked	[B]	[B]
C70400	W061	annealed	260	85
	WC55	light cold-worked	275	205
C70600	W061	annealed	275	105
	WC55	light cold-worked	310	240
C70620	WO61	annealed	275	105
	WC55	light cold-worked	310	240
C71000	W061	annealed	310	110
	WC55	light cold-worked	345	240
C71500	W061	annealed	360	125
	WC55	light cold-worked	370	240
C71520	WO61	annealed	360	125
	WC55	light cold-worked	370	240
C71640	W061	annealed	435	170
	WC55	light cold-worked	515	275
C72200	W061	annealed	310	110
	WC55	light cold-worked	345	205

[A] Light straightening operation is permitted.
[B] Where no properties are shown, strength requirements shall be as agreed upon between the purchaser and the manufacturer or supplier.

TABLE 4 Expansion Requirements

Temper	Copper or Copper Alloy UNS No.	Expansion of Tube Outside Diameter, in Percent of Original Outside Diameter
Annealed	C10800	30
	C12200	30
	C19400	20
	C23000	20
	C44300, C44400, C44500	20
	C68700	20
	C70400	30
	C70600	30
	C70620	30
	C71000	30
	C71500	30
	C71520	30
	C71640	30
	C72200	30
Light cold-worked	C10800	20
	C12200	20
	C19400	20
	C70400	20
	C70600	20
	C70620	20
	C71000	20
	C71500	20
	C71520	20
	C71640	20
	C72200	20
Annealed and light cold-worked, stress relieved	C23000	20
	C44300, C44400, C44500	20
	C68700	20

C44400; C44500; C60800; and C68700; when purchased if not supplied in an annealed temper (**Warning—**Mercury is a definite health hazard. With the Mercurous Nitrate Test, equipment for the detection and removal of mercury vapor produced in volatilization, and the use of protective gloves is recommended.)

12.1.2 The test specimens, cut 6 in. [152 mm] in length from the enhanced section shall withstand, without cracking, an immersion in the standard mercurous nitrate solution in Test Method B154 or immersion in the ammonia vapor solution as defined in Test Method B858.

12.1.3 Unless otherwise agreed upon between the manufacturer or supplier and the purchaser, the manufacturer shall have the option of using either the mercurous nitrate test or the ammonia vapor test. If agreement cannot be reached, the mercurous nitrate test standard shall be utilized.

12.1.4 If the ammonia vapor test is selected, the appropriate risk level pH value for the test solution shall be agreed upon by the manufacturer and purchaser, or alternately, if the purchaser defers to the manufacturer's expertise for the selection of the test pH value, the minimum value selected shall be 9.8.

13. Nondestructive Testing

13.1 Each tube shall be subjected to the eddy-current test in 13.1.1. Fully finished tube (see 4.3) may be tested in the final drawn, annealed, or heat-treatment temper or in the drawn temper prior to the final anneal or heat treatment, unless otherwise agreed upon between the manufacturer or supplier and the purchaser. Tube supplied welded and annealed (see 4.1.2) may be tested in the welded condition before anneal or

heat treatment, unless otherwise agreed upon between the manufacturer or supplier and the purchaser. The purchaser may specify either of the tests in 13.1.2 or 13.1.3 as an alternative to the eddy-current test.

13.1.1 *Eddy Current Test*—Each tube shall be passed through an eddy-current testing unit adjusted to provide information on the suitability of the tube for the intended application. Testing shall follow the procedures of Practice E243, except as modified in 13.1.1.2.

13.1.1.1 The depth of the round-bottom transverse notches and the diameters of the drilled holes in the calibrating tube used to adjust the sensitivity of the test unit are shown in Table 5 or Table 6 and Table 7 or Table 8 respectively.

13.1.1.2 The discontinuities used to calibrate the test system may be placed in the strip from which the tube will be manufactured. These calibration discontinuities will pass through the continuous operations of forming, welding, and eddy-current testing. The test unit sensitivity required to detect the resultant discontinuities shall be equivalent to or greater than that required to detect the notches or drilled holes of Table 5 or Table 6 and Table 7 or Table 8 respectively, or other calibration discontinuities that may be used by mutual agreement between the manufacturer or supplier and the purchaser. Calibration discontinuities may be on the outside tube surface, the internal tube surface, or through the tube wall and shall be spaced to provide signal resolution adequate for interpretation. Each calibration discontinuity shall be detected by the eddy-current tester.

13.1.1.3 Tubes that do not actuate the signaling device of the eddy-current tester shall be considered as conforming to the requirements of this test. Tubes causing irrelevant signals because of moisture, soil, and like effects may be reconditioned and retested. Such tubes, when retested to the original test parameters, shall be considered to conform if they do not cause output signals beyond the acceptable limits. Tubes causing irrelevant signals because of visible and identifiable handling marks may be retested by the hydrostatic test prescribed in 13.1.2, or the pneumatic test prescribed in 13.1.3. Tubes meeting requirements of either test shall be considered to conform if the tube dimensions are within the prescribed limits, unless otherwise agreed to by the manufacturer or supplier and the purchaser.

13.1.2 *Hydrostatic Test*—When specified, each tube selected in accordance with 13.1 shall withstand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 7000 psi [48 MPa], determined by the following equation for thin hollow cylinders under tension. The tube need not be tested at a hydrostatic pressure over 1000 psig [7.0 MPa] unless so specified.

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

where:

P = hydrostatic pressure, psig [MPa],
t = thickness of tube wall, in. [mm],
D = outside diameter of the tube, in. [mm], and
S = allowable stress of the material, psi [MPa].

13.1.3 *Pneumatic Test*—When specified, each tube shall be subjected to an internal air pressure of 60 psig [400 kPa] minimum 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. Any evidence of leakage shall be cause for rejection.

TABLE 5 Notch Depth—Inch-Pound Values

NOTE 1—See Table 6 for notch depth—SI values.

Tube Wall Thickness, in.	Tube Outside Diameter, in.		
	Over ¼ to ¾, incl	Over ¾ to 1¼, incl	Over 1¼ to 3⅛, incl
Over 0.017–0.032	0.005	0.006	0.007
Incl 0.032–0.049	0.006	0.006	0.0075
Incl 0.049–0.083	0.007	0.0075	0.008
Incl 0.083–0.109	0.0075	0.0085	0.0095
Incl 0.109–0.120	0.009	0.009	0.011

TABLE 6 Notch Depth—SI Values

NOTE 1—See Table 5 for notch depth—inch-pound values.

Tube Wall Thickness, mm	Tube Outside Diameter, mm		
	Over 6 to 19, incl	Over 19 to 32, incl	Over 32 to 80, incl
Over 0.4–0.8	0.13	0.15	0.18
Incl 0.8–1.3	0.15	0.15	0.19
Incl 1.3–2.1	0.18	0.19	0.20
Incl 2.1–2.8	0.19	0.22	0.24
Incl 2.8–3.0	0.23	0.23	0.28

TABLE 7 Diameter of Drilled Holes—Inch-Pound Values

NOTE 1—See Table 8 for diameter of drilled holes—SI values.

Tube Outside Diameter	Diameter of Drilled Holes	Drill No.
in.	in.	
¼ –¾, incl	0.025	72
Over ¾ –1, incl	0.031	68
Over 1–1¼, incl	0.036	64
Over 1¼ –1½, incl	0.042	58
Over 1½ –1¾, incl	0.046	56
Over 1¾ –2, incl	0.052	55

TABLE 8 Diameter of Drilled Holes—SI Values

NOTE 1—See Table 7 for diameter of drilled holes—inch-pound values.

Tube Outside Diameter	Diameter of Drilled Holes	Drill No.
mm	mm	
6.0–19.0, incl	0.65	72
Over 19.0–25.4, incl	0.80	68
Over 25.4–31.8, incl	0.92	64
Over 31.8–38.1, incl	1.1	58
Over 38.1–44.4, incl	1.2	56
Over 44.4–50.8, incl	1.3	55

14. Dimensions, Mass, and Permissible Variations

14.1 *Diameter*—The outside diameter of the tubes shall not vary from that specified by more than the amounts shown in Table 9 or Table 10 as measured by "go" and "no-go" ring gages. Where no values are shown in the table, dimensions shall be as agreed upon between the purchaser and the manufacturer or supplier.