Designation: B 395/B 395M – 08

Standard Specification for U-Bend Seamless Copper and Copper Alloy Heat Exchanger and Condenser Tubes[1]

This standard is issued under the fixed designation B 395/B 395M; 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[2] establishes the requirements for condenser, evaporator, and heat exchanger U-bend tubes that are manufactured from seamless copper and copper alloy tube.

1.2 The following safety hazard caveat pertains only to the test methods described in this specification.

1.2.1 *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 to determine the applicability of regulatory limitations prior to use.*

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

1.4 This specification is applicable to product 2 in. [50 mm] or less, inclusive, in diameter.

1.5 The product shall be produced from one of the following coppers or copper alloys, as specified in the ordering information:

Copper or Copper Alloy UNS No.	Previously Used Designation	Type of Metal
C10200	OF[A]	oxygen-free without residual deoxidants
C10300	...	oxygen-free, extra low phosphorus
C10800	...	oxygen-free, low phosphorus
C12000	DLP[A]	phosphorized, low residual phosphorus
C12200	DHP[A]	phosphorized, high residual phosphorus
C14200	DPA[A]	phosphorized, arsenical
C19200	...	phosphorized, 1 % iron
C23000	...	red brass
C44300	Type B	admiralty metal
C44400	Type C	admiralty metal
C44500	Type D	admiralty metal
C60800	...	aluminum bronze
C68700	Type B	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)
C72200	...	copper-nickel

[A] Designations listed in Classification B 224.

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:

2.2 *ASTM Standards:* [3]

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

B 154 Test Method for Mercurous Nitrate Test for Copper Alloys

B 224 Classification of Coppers

B 601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast

B 846 Terminology for Copper and Copper Alloys

B 858 Test Method for Ammonia Vapor Test for Determining Susceptibility to Stress Corrosion Cracking in Copper Alloys

B 900 Practice for Packaging of Copper and Copper Alloy Mill Products for U.S. Government Agencies

E 3 Guide for Preparation of Metallographic Specimens

E 8 Test Methods for Tension Testing of Metallic Materials

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

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 53 Test Method for Determination of Copper in Unalloyed Copper by Gravimetry

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

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[2] For *ASME Boiler and Pressure Vessel Code* applications see related Specification SB-395 in Section II of that Code.

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

[4] Withdrawn.

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

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)
E 112 Test Methods for Determining Average Grain Size
E 118 Test Methods for Chemical Analysis of Copper-Chromium Alloys
E 243 Practice for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes
E 255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition
E 478 Test Methods for Chemical Analysis of Copper Alloys

3. Terminology

3.1 For the definitions of terms related to copper and copper alloys, refer to Terminology B 846.

3.2 *Definitions:*

3.2.1 *u-bend tube*, *n*—a tube bent 180° in a single plane into a U-shape.

3.2.2 *dual-gage tube*, *n*—a tube which has more than one wall-gage thickness contained within the length of the tube.

3.2.3 *squareness of cut*, *n*—the maximum deviation of one side of a cross section of tube from the opposite side, when measured against the projected perpendicularity of the plane of the projected center of the tube at the ends.

4. Ordering Information

4.1 Orders for product under this specification shall include the following information:

4.1.1 ASTM designation and year of issue,

4.1.2 Copper or copper alloy UNS No. designation (Section 6),

4.1.3 Temper (Section 7),

4.1.4 *Dimensions*—X–diameter and wall thickness of the tube (see 12.1 and 12.2),

4.1.5 Schedule of bending radii (see 12.2.5),

4.1.6 Length of U-bend tube legs (see 12.2.8),

4.1.7 If the product is to be subsequently welded (see Table 1), and

4.1.8 If the product is to be for U.S. Government.

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

4.2.1 Heat identification or traceability details.

4.2.2 Tension test (see 9.1),

4.2.3 Relief anneal of U-bent portion of copper-nickel U-bend tubes (see 7.6),

4.2.4 Dual-gage, a schedule of tubes required in dual-gage and length of heavy gage section must be furnished with this option (see 5.2.2 and 12.2.3),

4.2.5 Certification, if required (see 21), and

4.2.6 Mill Test Report, if required (see 22).

4.3 In addition, when material is purchased for agencies of the U.S. Government, it shall be in accordance with the requirements specified in the Supplementary Requirements section, when specified in the contract or purchase order.

5. Materials and Manufacture

5.1 *Materials*:

5.1.1 The material of manufacture shall be of such quality and purity that the finished product shall have the properties and characteristics prescribed in this specification for the applicable alloy and temper.

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

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

5.2 *Manufacture*:

5.2.1 The product shall be manufactured by such hot working, cold working and annealing processes as to produce a uniform wrought structucture in the finished product.

5.2.2 Tubes required to be U-bent to a small radius shall, if specified, be furnished as dual-gage tubes.

5.2.2.1 These tubes shall be made prior to U-bending with the wall thickness of the central section of the tube length, increased the equivalent of one Stubs' or Birmingham Wire Gage (BWG) thicker than the wall thickness specified for the straight leg portion of the U-bend tube.

5.2.2.2 Unless otherwise specified, dual-gage tubes shall be made to constant inside diameter; that is, the increased wall thickness shall be obtained by increasing the outside diameter of the finished tube in the central heavy gage section.

5.2.3 The bent portion of the U-bend tube shall be substantially uniform in curvature.

6. Chemical Composition

6.1 The material shall conform to the chemical composition requirements specified in Table 1 for the copper or copper alloy UNS No. specified in the ordering information.

6.1.1 Results of analysis on a product (check) sample shall conform to the composition requirements within the permitted analytical variance specified in Table 1

6.2 These composition limits do not preclude the presence of unnamed elements. By agreement between the manufacturer and purchaser, limits may be established for elements not specified.

6.3 *Copper Alloy UNS No. C19200*—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 99.8 % minimum.

6.4 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 %.

6.4.1 When all the elements in Table 1 are analyzed, their sum shall be as shown in the following table.

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C60800	99.5
C70400	99.5
C70600	99.5
C70620	99.5
C71000	99.5
C71500	99.5
C71520	99.5
C72200	99.8

6.5 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 %.

TABLE 1 Chemical Requirements

Copper or Copper Alloy UNS No.	Composition,%												
	Copper[A]	Tin	Aluminum	Nickel, incl Cobalt	Lead, max	Iron	Zinc	Manganese	Arsenic	Antimony	Phosphorus	Chromium	Other Named Elements
C10200[A,B]	99.95 min	...	...	...	...	...	...	...	...	...	...	...	10 ppm max O
C10300[A]	99.95[C] min	...	...	...	...	...	...	...	...	...	0.001–0.005	...	...
C10800[A]	99.95[C] min	...	...	...	...	...	...	...	...	...	0.005–0.012	...	...
C12000[A]	99.90 min	...	...	...	...	...	...	...	...	...	0.004–0.012	...	...
C12200[A]	99.9 min	...	...	...	...	...	...	...	...	...	0.015–0.040	...	...
C14200[A]	99.4 min	...	...	...	...	...	...	...	0.15–0.50	...	0.015–0.040	...	...
C19200[D]	98.5 min	...	...	...	...	0.8–1.2	0.20 max	...	...	...	0.01–0.04	...	...
C23000[D]	84.0–86.0	...	...	...	0.05	0.05 max	remainder	...	...	...	...	...	...
C44300[E]	70.0–73.0	0.9–1.2	...	...	0.07	0.06 max	remainder	...	0.02–0.06	...	...	...	...
C44400[E]	70.0–73.0	0.9–1.2	...	...	0.07	0.06 max	remainder	...	...	0.02–0.10	...	...	...
C44500[E]	70.0–73.0	0.9–1.2	...	...	0.07	0.06 max	remainder	...	...	...	0.02–0.10	...	...
C60800[A,F]	remainder	...	5.0–6.5	...	0.10	0.10 max	...	...	0.02–0.35	...	...	...	...
C68700[A,F]	76.0–79.0	...	1.8–2.5	...	0.07	0.06 max	remainder	...	0.02–0.06	...	...	...	...
C70400[A,F]	remainder	...	...	4.8–6.2	0.05	1.3–1.7	1.0 max	0.30 to 0.8	...	...	...	...	...
C70600[A,F]	remainder	...	...	9.0–11.0	0.05[G]	1.0–1.8	1.0 max[G]	1.0 max[G]	...	...	...	...	...
C70620[A,F]	86.5 min	...	...	9.0–11.0	0.02	1.0–1.8	0.50 max	1.0 max	...	...	0.02 max	...	0.05C max 0.02S
C71000[A,F]	remainder	...	...	19.0–23.0	0.05[G]	1.0 max	1.0 max	1.0 max[G]	...	...	[G]	...	[G]
C71500[A,F]	remainder	...	...	29.0–33.0	0.05[G]	0.40–1.0	1.0 max[G]	1.0 max	...	...	...	...	[C]
C71520[A,F]	65.0 min	...	...	29.0–33.0	0.02	0.40–1.0	0.50 max	1.0 max	...	...	0.02 max	...	0.05C max 0.02S max
C72200[A,D]	remainder	...	...	15.0–18.0	0.05[G]	0.50–1.0	1.0 max[G]	1.0 max	...	...	...[G]	0.30–0.70	[G,H]

[A] Silver counting as copper.
[B] This is a high conductivity copper which has, in the annealed condition, a minimum conductivity of 100 % IACS.
[C] Includes P.
[D] Cu + sum of named elements, 99.8 % min.
[E] Cu + sum of named elements, 99.6 % min.
[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] Silicon shall be 0.03 % max, titanium shall be 0.03 % max.

6.5.1 When all the elements in Table 1 are analyzed, their sum shall be as shown in the following table.

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C23000	99.8
C44300	99.6
C44400	99.6
C44500	99.6
C68700	99.5

7. Temper

7.1 Tempers, as defined in Practice B 601, are as follows:

7.2 Prior to U-bending, tubes of Copper Alloy UNS Nos. C23000, C44300, C44400, C44500, C60800, C68700, C70400, C70600, C70620, C71000, C71500, C71520, and C72200 shall be in the annealed temper (O61), unless otherwise specified in the purchase order.

7.3 Prior to bending, U-bend tubes of Copper Alloy UNS Nos. C10200, C10300, C10800, C12000, C12200, and C14200 shall be in light drawn temper (H55). Tubes of Copper Alloy UNS Nos. C70400, C70600, C70620, and C72200 shall, if specified, be made in the light-drawn temper (H55).

7.4 Prior to bending, U-bend tubes of Copper Alloy UNS No. C19200 shall be in the annealed (O61) or light drawn temper (H55) as specified.

7.5 Prior to bending, U-bend tubes of Copper Alloy UNS No. C71500 or C71520 shall be made in the drawn, stress-relieved temper (HR50), when specified.

7.6 The U-bend portion of tubes furnished in Copper Alloy UNS Nos. C23000, C44300, C44400, C44500, C60800, and C68700 shall be relief annealed (HR) after bending. If specified, the U-bend portion of tubes furnished in Copper Alloy UNS Nos. C70400, C70600, C70620, C71000, C71500, C71520, and C72200 shall be relief annealed (HR) after bending.

NOTE 2—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, C60800, and C68700 be subjected to a stress relieving (HR) 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 by the manufacturer and purchaser.

8. Grain Size of Annealed Tempers

8.1 Samples of annealed–temper (O61) tubes selected for test shall be subjected to microscopical examination at a magnification of 75 diameters and shall show uniform and complete recrystallization.

8.2 Materials other than Copper Alloy UNS No. C19200 shall have an average grain size within the limits of 0.010 to 0.045 mm.

8.3 The requirements of this section do not apply to product of the light-drawn temper (H55) drawn, stress-relieved temper (HR50), or to the U-bent portion of the product.

9. Mechanical Property Requirements

9.1 *Tensile Strength Requirements*:

9.1.1 Product specified to meet the requirements of *ASME Boiler and Pressure Vessel Code* shall have tensile properties as prescribed in Table 2 for product specified in inch-pound units or Table 3 for product specified in SI units. When tested in accordance with Test Methods E 8 or E 8M.

10. Performance Requirements

10.1 *Expansion Test*:

10.1.1 When specified in the contract or purchaser order, tube specimens selected for test shall withstand the expansion shown in Table 4 when expanded in accordance with Test Method B 153.

10.1.2 The expanded tube shall show no cracking or other defects visible to the unaided eye.

10.2 *Flattening Test*:

10.2.1 When specified in the contract or purchase order, the flattening test described in the Test Method section in 17.2.1.3 shall be performed.

10.2.2 During inspection, the flattened areas of the test specimen shall be free of defects, but blemishes of a nature that do not interfere with the intended application are acceptable.

TABLE 2 Tensile Requirements

Copper or Copper Alloy UNS No.	Temper Designation		Tensile Strength, min, ksi [B]	Yield Strength,[A] min, ksi [B]	Elongation in 2 in., min, %
	Standard	Former			
C10200, C10300, C10800, C12000, C12200, C14200	H55	light drawn	36	30	...
C19200	H55	light drawn	40	35	...
C19200	O61	annealed	38	12	...
C23000	O61	annealed	40	12	...
C44300, C44400, C44500	O61	annealed	45	15	...
C60800	O61	annealed	50	19	...
C68700	O61	annealed	50	18	...
C70400	O61	annealed	38	12	...
C70400	H55	light drawn	40	30	...
C70600, C70620	O61	annealed	40	15	...
C70600, C70620	H55	light drawn	45	35	...
C71000	O61	annealed	45	16	...
C71500, C71520	O61	annealed	52	18	...
For wall thicknesses up to 0.048 in., incl	HR50	drawn, stress-relieved	72	50	12
For wall thicknesses over 0.048 in.	HR50	drawn, stress-relieved	72	50	15
C72200	O61	annealed	45	16	...
C72200	H55	light drawn	50	45	...

TABLE 3 Tensile Requirements (SI)

Copper or Copper Alloy UNS No.	Temper Designation		Tensile Strength, min, MPa	Yield Strength,[A] min, MPa	Elongation in 50.8 mm, min, %
	Standard	Former			
C10200, C10300, C10800, C12000, C12200, C14200	H55	light drawn	250	205	...
C19200	H55	light drawn	275	240	...
C19200	O61	annealed	260	85	...
C23000	O61	annealed	275	85	...
C44300, C44400, C44500	O61	annealed	310	105	...
C60800	O61	annealed	345	130	...
C68700	O61	annealed	345	125	...
C70400	O61	annealed	260	85	...
C70400	H55	light drawn	275	205	...
C70600, C70620	O61	annealed	275	105	...
C70600, C70620	H55	light drawn	310	240	...
C71000	O61	annealed	310	110	...
C71500, C71520:	O61	annealed	360	125	...
For wall thicknesses up to 1.2 mm, incl	HR50	drawn, stress-relieved	495	345	12
For wall thicknesses over 1.2 mm	HR50	drawn, stress-relieved	495	345	15
C72200	O61	annealed	310	110	...
C72200	H55	light drawn	345	310	...

TABLE 4 Expansion Requirements

Temper Designation		Copper or Copper Alloy UNS No.	Expansion of Tube Outside Diameter in Percent Of Original Outside Diameter
Standard	Former		
O61	annealed	C19200	30
		C23000	20
		C44300, C44400, C44500	20
		C60800	20
		C68700	20
		C70400	30
		C70600, C70620	30
		C71000	30
		C71500, C71520	30
		C72200	30
H55	light-drawn	C10200, C10300, C10800, C12000, C12200	20
		C14200	20
		C19200	20
		C70400	20
		C70600, C70620	20
		C72200	20
HR58	drawn, stress relieved	C71500, C71520	20

11. Other Requirements

11.1 *Mercurous Nitrate Test or Ammonia Vapor Test*:

11.1.1 The mercurous nitrate or ammonia vapor test is required only for Copper Alloy UNS Nos. C23000, C44300, C44400, C44500, C60800, and C68700. (**Warning**—Mercury is a definite health hazard and therefore equipment for the detection and removal of mercury vapor produced in volatilization is recommended. The use of rubber gloves in testing is advisable.)

11.1.2 The test specimens, cut 6 in. [150 mm] in length from both the U-bend and straight leg length, shall withstand, without cracking, an immersion in the standard mercurous nitrate solution in Test Method B 154 or immersion in the ammonia vapor solution as defined in Test Method B 858: the straight leg specimens shall include the finished tube ends.

NOTE 3—There is no standard test method to evaluate the effectiveness of a relief-anneal (HR) of the U–bend section of copper-nickel or copper-nickel-iron tubes with respect to stress-corrosion cracking susceptibility.

11.1.3 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.

11.1.4 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.

11.2 *Nondestructive Examination for Defects*:

11.2.1 Each tube, prior to bending, shall be subjected to the eddy-current test.

11.2.2 Tubes may be tested in the final drawn, annealed, or heat-treated temper or in the drawn temper prior to the final anneal or heat treatment at the option of the manufacturer.

11.2.3 Testing shall follow the procedures of Practice E 243.

11.2.4 Unless otherwise agreed upon between the manufacturer, or supplier, and the purchaser, the manufacturer shall have the option of calibrating the test equipment using either notch-depth or drilled-hole standards. If agreement cannot be reached, notch-depth standard shall be utilized.

11.2.5 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 and Table 7 for the material specified in the inch-pound system and Table 6 and Table 8 for material specified in the SI system.

TABLE 5 Notch Depth

Tube Wall Thickness, in.	Tube Outside Diameter, in.		
	Over ¼ to ¾ , incl	Over ¾ to 1¼ , incl	Over 1¼ to 2, 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)

Tube Wall Thickness, mm	Tube Outside Diameter, mm		
	Over 6 to 19, incl	Over 19 to 32, incl	Over 32 to 50, incl
Over 0.43–0.81	0.13	0.15	0.18
Incl, 0.81 to 1.3	0.15	0.15	0.19
Incl, 1.3 to 2.1	0.18	0.19	0.20
Incl, 2.1 to 2.8	0.19	0.22	0.24
Incl, 2.8 to 3.0	0.23	0.23	0.28

TABLE 7 Diameter of Drilled Holes

Tube Outside Diameter, in.	Diameter of Drilled Holes, in.	Drill No.
¼ to ¾ , incl	0.025	72
Over ¾ , incl	0.031	68
Over 1–1¼ , incl	0.036	64
Over 1¼ –1½ , incl	0.042	58
Over ½ –¾ , incl	0.046	56
Over ¾ , incl	0.052	55

TABLE 8 Diameter of Drilled Holes (SI)

Tube Outside Diameter, mm	Diameter of Drilled Holes, mm	Drill No.
6.0–19.0, incl	0.635	72
Over 19.0–25.0, incl	0.785	68
Over 25.0–32.0, incl	0.915	64
Over 32.0–38.0, incl	1.07	58
Over 38.0–45.0, incl	1.17	56
Over 45.0–50.0, incl	1.32	55

11.2.6 Tubes that do not actuate the signaling device of the eddy-current tester shall be considered as conforming to the requirements of this test.

11.2.7 Tubes causing irrelevant signals because of moisture, soil, and minor mechanical damage may be reconditioned and retested.

11.2.8 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.

11.2.9 Tubes causing irrelevant signals because of visible and identifiable handling marks shall be considered in conformance if the tube dimensions are within the prescribed limits and if the tubes conform to the leak test requirements of 11.3.2 or 11.3.3, unless otherwise agreed to by the manufacturer and purchaser.

11.3 Each U-bend tube shall be tested to the requirements of either 11.3.2 or 11.3.3.

11.3.1 Unless otherwise specified, the manufacturer shall have the option of the leak test to be used.

11.3.2 *Hydrostatic Test*—Each tube shall withstand an internal hydrostatic-pressure sufficient to subject the material to a fiber stress of 7000 psi [48 MPa] without evidence of leakage. The tube need not be tested at a hydrostatic pressure of over a gage pressure of 1000 psi [6.9 MPa], unless so specified. The 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, psi [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].

11.3.3 *Pneumatic Test*—Each tube shall be subjected to an internal air gage pressure of 60 psi [400 kPa], minimum. The product shall maintain pressure and show no evidence of leakage for 5 s. The test method used shall permit 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.

12. Dimensions, Mass, and Permissible Variations

12.1 *Tube Diameter*—The outside diameter of the straight leg portion of the tube, exclusive of the central heavy gage portion, shall not vary from that specified by more than the amounts shown in Table 9 for product specified in the inch-pound system or Table 10 for product specified in the SI system as measured by “go” and “no-go” ring gages.

12.2 *Thickness*:

12.2.1 *Tubes Ordered to Minimum Wall*—Prior to bending, the wall thickness of the single-gage tubes at the thinnest point shall not be less than the thickness specified. The maximum plus deviation from the specified wall at any point shall not exceed twice the value shown in Table 11 for product specified in the inch-pound system or Table 12 for product specified in the SI system.

12.2.2 *Tubes Ordered to Nominal Wall*—

12.2.2.1 Prior to bending the maximum plus and minus deviation from the nominal wall at any point shall not exceed the values shown in Table 11 for product specified in the inch-pound system or Table 12 for product specified in the SI system.

12.2.2.2 When tubes are required in dual-gage, the wall thickness of the heavy gage portion, prior to bending, shall conform to the applicable tolerances in Table 11 or Table 12 for the specified heavier gage (Note 4).

NOTE 4—The wall thickness of the heavy-gage section of the dual-gage tube shall be determined by adding one half the difference between the

TABLE 9 Diameter Tolerances

Outside Diameter, in.	Wall Thickness, in.			
	0.032	0.035	0.042	0.049 and Over
	Diameter Tolerance, Plus and Minus, in.			
Up to 0.500 incl	0.0025	0.0025	0.0025	0.0025
Over 0.500–0.740, incl	0.004	0.004	0.0035	0.003
Over 0.740–1.000, incl	0.006	0.005	0.0045	0.004
Over 1.000–1.250, incl	0.009	0.008	0.006	0.0045
Over 1.250–1.375, incl	...	...	0.008	0.005
Over 1.375–2.000, incl	...	...	...	0.006

TABLE 10 Diameter Tolerances (SI)

Outside Diameter, mm	Wall Thickness, mm			
	0.813	0.889	1.07	1.24 and Over
	Diameter Tolerance, Plus and Minus, mm			
Up to 12.0, incl	0.064	0.064	0.064	0.064
Over 12.0–18.0, incl	0.010	0.10	0.089	0.076
Over 18.0–25.0, incl	0.15	0.13	0.11	0.10
Over 25.0–35.0, incl	...	...	0.20	0.13
Over 35.0–50.0, incl	...	...	...	0.15

TABLE 11 Wall Thickness Tolerances

Wall Thickness, in.	Outside Diameter, in.		
	Over ⅛ to ⅝ , incl	Over ⅝ to 1, incl	Over 1 to 2, incl
	Wall Thickness Tolerances, Plus and Minus in.		
0.032, incl to 0.035	0.003	0.003	0.004
0.035, incl to 0.058	0.004	0.0045	0.0045
0.058, incl to 0.083	0.0045	0.005	0.005
0.083, incl to 0.120	0.005	0.0065	0.0065
0.120, incl to 0.134	0.007	0.007	0.0075

TABLE 12 Wall Thickness Tolerances (SI)

Wall Thickness, mm	Outside Diameter, mm		
	Over 3.0 to 16.0, incl	Over 16.0 to 25.0, incl	Over 25.0 to 50.0, incl
	Wall Thickness Tolerances, Plus and Minus mm		
0.813, incl to 0.889	0.076	0.076	0.10
0.889, incl to 1.47	0.10	0.11	0.11
1.47, incl to 2.11	0.11	0.13	0.13
2.11, incl to 3.05	0.13	0.17	0.17
3.05, incl to 3.40	0.18	0.18	0.19

outside diameter at the heavy gage and the outside diameter of the standard gage to the minimum measured wall thickness determined at either end of the tube.

12.2.3 *Wall Thickness of Tube in U-Bend Section*—The wall thickness of the tube at the apex of the U-bent section shall be not less than the value determined by the following equation:

$$t_f = t(2R)/(2R + D) \quad (2)$$

where:

t_f = thickness after bending, in. [mm],
t = specified thickness of minimum wall or specified nominal wall minus the permissible wall thickness tolerance, in. [mm],
R = centerline bend radius, in. [mm], and
D = nominal outside diameter of the tube, in. [mm]

Proof of conformance to this requirement shall be obtained by bending a tube specimen representative of the material offered to the scheduled radius of bend cutting the tube at the apex of the bend, measuring the tube wall at the cross section of this apex section, and comparing the measured value with the calculated value of t_f.

12.2.4 *Length of Central Heavy-Gage Section of Tube*—The nominal length of the heavy-gage section of the dual-gage tube prior to bending shall be as specified but in no case shall the length of the heavy-gage section be specified less than 4 in. [100 mm] nor less than the length of the bend measured along the centerline bend radius between the points of tangency. The tolerance on the length of the heavy gage section shall be plus 3 in. [76 mm], minus 0 in. [0 mm]. The transition from the larger tube diameter of the heavy-gage section to the diameter of the tube in the standard-gage section shall be gradual and take place in a distance of not less than ⅛ in. [3.2 mm] nor more than 1 in. [25 mm] measured parallel to the tube axis.

12.2.5 *Centering of U-Bend in Heavy-Gage Section of Tube*—U-bends in the dual-gage tube shall be centered substantially within the heavy-gage section of the tube. The heavy-gage section of the tube shall extend to or beyond the point of tangency, that is, the dimension a in Fig. 1 may be equal to or greater than 0 in. [0 mm]. The difference $(b - a)$ between the lengths of the heavy-gage section which extend

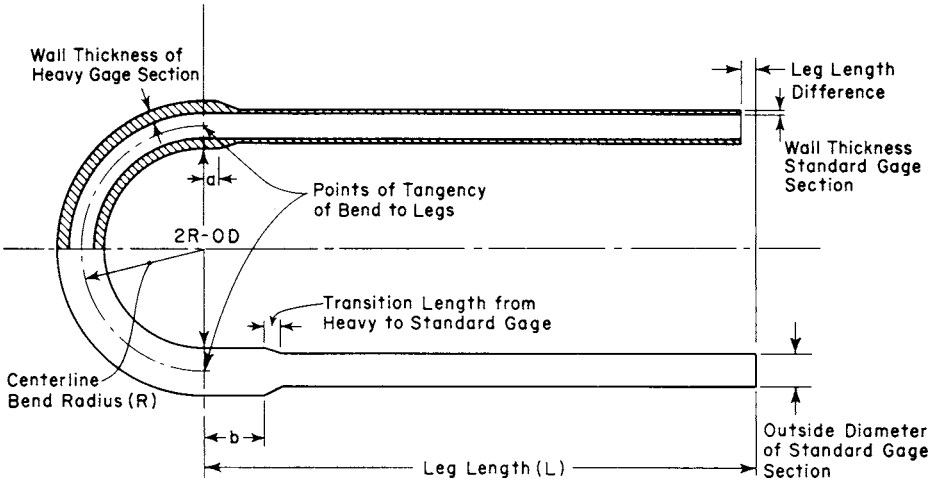

FIG. 1 Centering of U-Bend in Heavy Gage Section of Tube

beyond the point of tangency into the U-bend tube legs shall not exceed 1 in. [25 mm].

12.2.6 *Bending Radius*—The leg spacing, measured between the points of tangency of the bend to the legs shall not vary from the value ($2R$ – specified tube outside diameter) by more than 1/16 in. [1.6 mm] where R is the specified centerline bend radius (Note 5).

NOTE 5—The higher tensile properties recognized by the ASME Code for Copper Alloy UNS No. C71500 or C71520 in the drawn, stress-relieved temper (HR50) and Copper UNS Nos. C10200, C10300, C10800, C12000, C12200, C14200, and Copper Alloy No. C70400 in the light-drawn temper (H55) are obtained with some sacrifice of ductility. Similarly, though the ASME Code does not recognize Copper Alloy UNS No. C70600 or C70620 in the light-drawn temper (H55), tubes in this temper are frequently required.

NOTE 6—The radius of the bend of tubes of C71500 or C71520, in the drawn stress-relieved temper (HR50), shall not be less than 2.2 times the tube outside diameter for tubes with 0.049-in. [1.24 mm] wall, and not less than two times the tube outside diameter for tubes with 0.058 in. [1.47 mm] wall.

12.2.7 *Diameter of Tube in U-Bent Section*—Neither the major, nor the minor outside diameter of the tube at any one cross section included within the points of tangency of the bend shall deviate from the nominal diameter prior to bending by more than 10 %.

12.2.8 *Length of U-Bend Tube Legs*—The length L in Fig. 1 of the tube legs as measured from the point of tangency of the bend and the tube leg to the end of the tube leg shall not be less than that specified when measured at a temperature of 68°F [20°C], but may exceed the specified values by the amounts shown in Table 13 for product specified in the inch-pound system or Table 14 for product specified in the SI system.

TABLE 13 Tube Leg Tolerances

Specified Length, (*L*) ft	Tolerance all Plus, in.
Up to 20, incl	1/8
Over 20–30, incl	5/32
Over 30–60, incl	1/4
Over 60	3/8

TABLE 14 Tube Leg Tolerances (SI)

Specified Length, (*L*) mm	Tolerance all Plus, mm
Up to 6000, incl	3.2
Over 6000–9000, incl	4.0
Over 9000–18 000, incl	6.4
Over 18 000	9.5

12.2.8.1 The difference in length of the tube legs shall not be greater than 1/8 in. [3.2 mm], unless otherwise specified.

12.2.9 *Squareness of Cut*—The departure from squareness of the end of any tube shall not exceed the values given in Table 15 for product specified in the inch-pound system or Table 16 for product specified in the SI system. See Fig. 2.

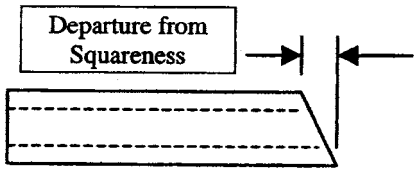

FIG. 2 Squareness of Cut

TABLE 15 Squareness Tolerances

Specified Outside Diameter, in.	Tolerance
Up to 5/8 , incl	0.010 in.
Over 5/8	0.016 in./in.

TABLE 16 Squareness Tolerances (SI)

Specified Outside Diameter, mm	Tolerance
Up to 16.0, incl	0.25 mm
Over 16.0	0.016 mm/mm

13. Workmanship, Finish, and Appearance

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

13.2 Annealed-temper (O61) tubes shall be clean and smooth, but may have a superficial, dull iridescent film on both the inside and outside surface. Drawn-temper tubes shall be clean and smooth, but may have a superficial film of drawing lubricant on the surfaces. A light oxide scale on the outside and inside surfaces of U-bend tubes shall be allowed for tubes which have been relief annealed.

14. Sampling

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

14.1.1 *Lot Size*—For purposes of testing, a lot shall consist of 600 tubes or fraction thereof, for tubes whose lengths prior to U-bending are up to and including 45 ft [13 800 mm] or 300 tubes or fraction thereof for tubes whose lengths prior to U-bending are over 45 ft [13 800 mm]. As tubes intended for U-bending are of different lengths depending on the bending radius, a lot of tubes for sampling purposes may include tubes of different lengths. If any order includes tubes whose lengths prior to bending are both under and over 45 ft [13 800 mm], those tubes shall be divided into separate lots as noted above.

14.1.2 *Portion Size*—Pieces from two tubes selected from each lot prior to bending.

14.2 *Chemical Analysis*:

14.2.1 Samples for chemical analysis shall be taken in accordance with Practice E 255. Drillings, millings, and so forth, shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 14.1.2 and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 0.33 lb [150 g].

14.2.1.1 Instead of sampling in accordance with Practice E 255, 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 semi-finished 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.

14.2.1.2 The number of samples taken for determination of chemical composition shall be as follows:

(a) 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.

(b) When samples are taken from the semi-finished product, a sample shall be taken to represent each 10 000 lb [4550 kg] or fraction thereof, except that not more than one sample shall be required per piece.

(c) 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.

(d) In the event that heat identification or traceability is required, the purchaser shall specify the details desired.

15. Number of Tests and Retests

15.1 *Test*:

15.1.1 *Chemical Analysis*—One composite sample shall be subjected to the test as defined in 14.2.

15.1.2 *Grain Size*—Two tubes shall be selected from each lot prior to bending and each tube shall be tested to verify the requirements in Section 8.

15.1.3 *Tensile Property Requirements*—Two tubes shall be selected from each lot prior to bending and each tube shall be tested to verify the requirements in Section 9.

15.1.4 *Expansion Test*—Two tubes shall be selected from each lot prior to bending and each tube shall be tested to verify the requirements in Section 10.

15.1.5 *Flattening Test*—Two tubes shall be selected from each lot prior to bending and each tube shall be tested to verify the requirement in 11.2.

15.1.6 *Mercurous Nitrate Test or Ammonia Vapor Test*—The two sample lengths selected for test specimens in 14.1 shall be tested to verify the requirements of 11.1.

15.2 *Retest*:

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

15.2.2 The retest shall be as directed in the product specification for the initial test, except the number of test specimens shall be twice that normally required for the specified test.

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

16. Specimen Preparation

16.1 *Chemical Analysis*:

16.1.1 Sample preparation shall be in accordance with Practice E 255.

16.1.2 Analytical specimen preparation shall be the responsibility of the reporting laboratory.

16.2 *Grain Size*—The test specimen shall be prepared in accordance with Test Method E 3 and shall approximate a radial longitudinal section of the tube.

16.3 *Tension Test*:

16.3.1 Tension test specimens shall be of the full section of tube and shall conform to the requirements of the Test Specimen section of Test Methods E 8 or E 8M, as applicable unless the limitations of the testing machine precludes 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 or E 8M shall be used when a full section specimen cannot be tested.

16.3.2 Tension test results on product covered by this specification are not seriously affected by variations in speed of testing. The rate of stressing to the yield strength shall not exceed 100 ksi/min [690 MPa/mm]. Above the yield strength, the movement per minute of the testing machine head under load should not exceed 0.5 in./in. [0.5 mm/mm], as appropriate of gage length (or distance between grips for full section specimens).

16.4 *Expansion Test Specimen*—Test specimens shall conform to the requirements of the Specimen Preparation section of Test Method B 153.

16.5 *Mercurous Nitrate Test or Ammonia Vapor Test*:

16.5.1 A sufficient length of tube taken from each of the two sample lengths selected for test specimens (see 14.1) shall be U-bent to the smallest radius in the order and shall be subjected to the same relief-annealed (HR) treatment to be used for this size in producing the order.

16.5.2 The test specimens shall be cut 6 in. [150 mm] in length from both the U-bend and straight-leg length.

16.5.3 The straight-leg specimens shall include the finished-tube ends.

16.6 *Flattening Test*—A test specimen shall be cut to a length that will allow the tube to be flattened at three (3) places along the length, with each flattened area to be at least 2 in [50 mm] in length. When the temper is other than annealed, the sample may be annealed prior to testing.

17. Test Methods

17.1 *Chemical Composition*:

17.1.1 Chemical compositions for all other alloys, in case of disagreement, shall be determined as follows:

Element	Range	Test Method
Copper	99.75 to 99.99	E 53, Electrolytic
Copper	70.0 to 99.75	E 478, Electrolytic
Tin	0.9 to 1.2	E 478, Photometric
Aluminum	1.8 to 6.5	E 478
Nickel, incl Cobalt	4.8 to 33.0	E 478, Gravimetric
Lead	0.05 to 0.10	E 478, Atomic Absorption,
Iron	0.04 to 1.8	E 478
Zinc	14.0 to 30.0	E 478, Titrimetric
Zinc	to 1.0	E 478, Atomic Absoprtion
Manganese	to 1.0	E 62
Arsenic	0.02 to 0.5	E 62
Antimony	0.02 to 0.1	E 62
Phosphorus	0.001 to 0.04	E 62
Chromium	0.30 to 0.70	E 118

17.2 *Other Tests*:

17.2.1 The product furnished shall conform to all other requirements when subjected to testing in accordance with the following table:

Ammonia Vapor Test	B 858
Eddy Current	E 243
Expansion (Pin Test)	B 153
Grain Size	E 112
Mercurous Nitrate	B 154
Tension	E 8, E 8M, as applicable

17.2.1.1 *Grain Size*—In case of dispute, the intercept method of Test Mehod E 112 shall be followed.

17.2.1.2 *Tension Test*—Whenever tension test results are obtained from both full size and from machined test specimens and they differ, the results obtained from full-size specimens shall prevail.

17.2.1.3 *Flattening Test*—Each test specimen shall be flattened in a press at three (3) places along the length, each new place to be rotated on its axis approximately one-third turn from the last flattened area. Each flattened area shall be at least 2 in. [50 mm] in length. A flattened test specimen shall allow a micrometer caliper set at three (3) times the wall thickness to pass freely over the flattened area. The flattened areas shall be inspected for surface defects.

18. Significance of Numerical Limits

18.1 For purpose of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Practice E 29.

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	nearest unit in the last right-hand place of figures
Tensile strength	nearest ksi [nearest 5 MPa]
Elongation	nearest 1 %
Expansion	nearest 1 %
Grain size	nearest multiple of 0.005 mm

19. Inspection

19.1 The manufacturer, or supplier, shall inspect and make necessary tests to verify that the product furnished conforms to the specification requirements.

19.2 Source inspection of the product by the purchaser may be agreed upon between the manufacturer, or supplier, and the purchaser as part of the purchase order. In such case, the nature of the facilities needed to satisfy the inspector, representing the purchaser, that the product is being furnished in accordance with the specification shall be included in the agreement. All testing and inspection shall be conducted so as not to interfere unnecessarily with the operation of the works.

19.3 When mutually agreed upon, the manufacturer, or supplier, and the purchaser shall conduct the final inspection simultaneously.

20. Rejection and Rehearing

20.1 *Rejection*:

20.1.1 Product that fails to conform to the requirements of this specification when inspected or tested by the purchaser, or purchaser's agent, shall be subject to rejection.

20.1.2 Rejection shall be reported to the manufacturer or supplier promptly. In addition, a written notification of rejection shall follow.

20.1.3 In case of dissatisfaction with results of the test upon which rejection is based, the manufacturer, or supplier, shall have the option to make claim for rehearing.

20.2 *Rehearing*:

20.2.1 As a result of product rejection, the manufacturer, or supplier, shall have the option to make claim for a retest to be conducted by the manufacturer, or supplier, and the purchaser. Samples of the rejected product shall be taken in accordance with the product specification and subjected to test by both parties using the test method(s) specified in the product specification, or alternately, upon agreement of both parties, an independent laboratory may be selected for the test(s) using the test method(s) specified in the product specification.

21. Certification

21.1 When specified in the contract or purchase order, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and requirements have been met.

21.2 When identified in the ordering information that product is purchased for *ASME Boiler and Pressure Vessel Code* applications, certification to this specification is mandatory.

22. Mill Test Report

22.1 When specified in the contract or purchase order, a report of test results shall be furnished.

23. Packaging and Package Marking

23.1 *Packaging*:

23.1.1 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 and to afford protection from the normal hazards of transportation.

23.2 *Package Marking*:

23.2.1 Each shipping unit shall be legibly marked with the purchase order number, metal or alloy designation, temper, size, shape, total length of piece count, or both, and name of supplier. The specification number shall be shown, when specified.

24. Keywords

24.1 condenser tube; copper; copper alloy; dual-gage; evaporator; heat exchanger; U-bend tube; C10200; C10300; C10800; C12000; C12200; C14200; C19200; C23000; C44300; C44400; C44500; C60800; C68700; C70400; C70600; C70620; C71000; C71500; C71520; C72200

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:*[5]

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:*[5]

MIL-STD-129 Marking for Shipment and Storage

S1.1.3 *ASTM Standard:*

B 900 Practice for Packaging of Copper and Copper-Alloy Mill Products for U.S. Government Agencies

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 may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved of 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 Practice B 900.

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.

[5] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.

SUMMARY OF CHANGES

Committee B05 has identified the location of selected changes to this specification since the last issue (B 395/B 395M – 02) that may impact the use of this standard. (Approved April 1, 2008)

(*1*) General rewrite of the specification to comply with the outline of form, including miscellaneous working changes.