Designation: ~~B395/B395M – 08~~ B395/B395M – 13

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

This standard is issued under the fixed designation B395/B395M; 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.*~~

1.2 *Units*—The values stated in either SI units or inch-pound 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 specification is applicable to product 2 in. [50 mm] or less, inclusive, in diameter.

1.4 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~~

[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.

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

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 B224.

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

1.5.1 *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 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:

2.2 *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

B601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast

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~~E8/E8M Test Methods for Tension Testing of Metallic Materials

~~E8M Test Methods for Tension Testing of Metallic Materials [Metric] (Withdrawn 2008)[4]~~

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

E53 Test Method for Determination of Copper in Unalloyed Copper by Gravimetry

E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)[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

E2575 Test Method for Determination of Oxygen in Copper and Copper Alloys

2.3 *Other Standards:*[5]

ASME Boiler and Pressure Vessel 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] 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.

3. Terminology

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

3.2 ~~*Definitions:*~~*Definitions of Terms Specific to This Standard:*

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

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

3.2.2 *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.

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

4. Ordering Information

4.1 ~~Orders~~ Include the following specified choices when placing orders for product under this ~~specification shall include the following information:~~specification, as applicable:

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 (must include the number of pieces of each 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 Intended application, and

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

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

4.2.1 Heat identification or traceability ~~details.~~details (see 5.1.2).

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 Flattening Test (Section 10.2).

4.2.6 Expansion Test (Section 10.1).

4.2.7 Certification, if required (see Section 21), and

4.2.8 Mill Test Report, if required (see Section 22).

4.3 ~~In addition, when material~~ If product 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.

4.4 If product is ordered for ASME Boiler and Pressure Vessel Code Application (See Certification Section 21).

5. Materials and Manufacture

5.1 *Materials:*

5.1.1 The material of manufacture shall be of the copper alloys defined in 1.4 and 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~~ When specified in the contract or purchase order that 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~~structure 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.

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]~~	~~...~~	~~...~~	~~...~~	~~...~~	~~...~~
C70600[A,F]	remainder	...	...	9.0–11.0	0.05	1.0–1.8	1.0 max	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
C71000[A,F,G]	remainder	...	...	19.0–23.0	0.05[G]	1.0 max	1.0 max[G]	1.0 max[G]	...	...	[G]	...	0.02S max [G]
~~C71500[A,F]~~	~~remainder~~	~~...~~	~~...~~	~~29.0–33.0~~	~~0.05[G]~~	~~0.40–1.0~~	~~1.0 max[G]~~	~~1.0 max~~	~~...~~	~~...~~	~~...~~	~~...~~	[C]
C71500[A,F]	remainder	...	...	29.0–33.0	0.05	0.40–1.0	1.0 max	1.0 max	...	...	...	...	...
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
C72200[A,D,G]	remainder	...	...	15.0–18.0	0.05[G]	0.50–1.0	1.0 max[G]	1.0 max	...	...	...[G]	0.30–0.70	0.02S max [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~~101 % 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. 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. designation 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.~~and analysis required for unnamed elements.

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 %.

~~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 B601, 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~~for 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.~~Grain size shall be the standard requirement for all product in annealed tempers.

8.2 ~~Materials other than Copper Alloy UNS No. C19200 shall have an~~ Acceptance or rejection based upon grain size shall depend only on the average grain size of a test specimen taken from each of two sample portions and each specimen shall be within the limits of 0.010 to 0.045 ~~mm.~~mm when determined in accordance with Test Method E112.

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 :*~~ *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 ~~E8~~E8/E8M ~~or E8M~~.

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 B153.

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~~ accordance with Test Method ~~section~~B968/B968M ~~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.

10.3 *Residual Stress Test:*

10.3.1 Product manufactured from Copper Alloy UNS Nos. C23000, C44300, C44400, C44500, C60800 and C68700 shall be tested for residual stress according to the requirements of Test Method B154 or Test Method B858 and show no signs of cracking.

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.

10.3.2 When the Ammonia Vapor Test is used, the test pH value appropriate for the intended application shall be 10 unless otherwise specified by the purchaser.

10.3.3 Residual stress test specimens shall be from both the U-bend and straight leg length and tested without bending, springing, polishing, or any other preparation, except as allowed by the test method.

NOTE 3—A residual stress test provides information about the adequacy of the stress relief of the material. Stress relief annealing is a method of thermal stress relief. 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. Other Requirements

~~11.1 *Mercurous Nitrate Test or Ammonia Vapor Test:*~~

TABLE 2 Tensile Requirements (Inch-Pound)

NOTE 1—For SI values, see Table 3.

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~~Temper Code	~~Former~~Temper Name			
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	...