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# Standard Specification for U-Bend Seamless Copper and Copper Alloy Heat Exchanger and Condenser Tubes<sup>1</sup>

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 ( $\epsilon$ ) 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<sup>2</sup> establishes the requirements for condenser, evaporator, and heat exchanger U-bends that are manufactured from seamless copper and copper alloy tube.

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

~~1.3~~1.4 This specification is applicable to product 2 in. [50 mm] or less, inclusive, in diameter.

1.4 ~~The~~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 <sup>A</sup>	oxygen-free without residual deoxidants
C10300	...	oxygen-free, extra low phosphorus
C10800	...	oxygen-free, low phosphorus
C12000	DLP <sup>A</sup>	phosphorized, low residual phosphorus
C12200	DHP <sup>A</sup>	phosphorized, high residual phosphorus
C14200	DPA <sup>A</sup>	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

<sup>A</sup> Designations listed in Classification B 224.

<sup>1</sup> 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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<sup>2</sup> 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.

1.5 The following pertains only to the test method described in Sections 11 and 15, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

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

2.2 *ASTM Standards*:<sup>3</sup>

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 and Copper Alloys](#)<sup>3</sup>

~~B 170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes~~<sup>3</sup> [Test Method for Mercurous Nitrate Test for Copper Alloys](#)

B 224 [Classification of Coppers](#)

B 601 [Practice 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 [Practice 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 \[Metric\]](#)

E 29 [Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications](#)

E 53 [Test Methods for Chemical Analysis of Copper](#)

~~E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes~~<sup>6</sup> [Test Method for Determination of Copper in Unalloyed Copper by Gravimetry](#)

E 62 [Test Methods for Chemical Analysis of Copper and Copper Alloys \(Photometric Methods\)](#)<sup>6</sup>

~~E 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys~~<sup>6</sup> [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. [/astm-b395-b395m-08](#)

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.

~~3.3 Definitions of Terms Specific to This Standard:~~

~~3.3.1 squareness of cut~~

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 Tension test (see

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



TABLE 1 Chemical Requirements

Copper or Copper Alloy UNS No.	Composition, %											Other Named Elements	
	Copper <sup>A</sup>	Tin	Aluminum	Nickel, incl Cobalt	Lead, max	Iron	Zinc	Manganese	Arsenic	Antimony	Phosphorus		Chromium
G10200 <sup>B</sup>	99.95 min <sup>C</sup>	..	..	..	..	..	..	..	..	..	..	..	10 ppm max <sup>D</sup>
C10200 <sup>A,B</sup>	99.95 min	..	..	..	..	..	..	..	..	..	..	..	10 ppm max <sup>D</sup>
G10900	99.95 <sup>D</sup>	..	..	..	..	..	..	..	..	0.001–0.005	..	..	..
C10300 <sup>A</sup>	99.95 <sup>C</sup>	..	..	..	..	..	..	..	..	0.001–0.005	..	..	..
G10900	99.95 <sup>D</sup>	..	..	..	..	..	..	..	..	0.005–0.012	..	..	..
C10800 <sup>A</sup>	99.95 <sup>C</sup>	..	..	..	..	..	..	..	..	0.005–0.012	..	..	..
G12000	99.99	..	..	..	..	..	..	..	..	0.004–0.012	..	..	..
C12000 <sup>A</sup>	99.90 min	..	..	..	..	..	..	..	..	0.004–0.012	..	..	..
G12200	99.99	..	..	..	..	..	..	..	..	0.0045–0.010	..	..	..
C12200 <sup>A</sup>	99.9 min	..	..	..	..	..	..	..	..	0.015–0.040	..	..	..
G14200	99.40	..	..	..	..	..	..	..	..	0.015–0.040	..	..	..
C14200 <sup>A</sup>	99.4 min	..	..	..	..	..	..	..	..	0.015–0.040	..	..	..
G10200 <sup>E</sup>	98.5 min	..	..	..	..	..	..	..	..	0.01–0.04	..	..	..
C19200 <sup>D</sup>	98.5 min	..	..	..	..	..	..	..	..	0.01–0.04	..	..	..
G29000 <sup>F</sup>	84.0–86.0	..	..	..	0.05	remainder	..	..	..	..	..	..	..
C23000 <sup>D</sup>	84.0–86.0	..	..	..	0.05 max	remainder	..	..	..	..	..	..	..
G44300 <sup>F</sup>	70.0–73.0	0.9–1.2	..	..	0.07	remainder	..	..	0.02–0.06	..	..	..	..
C44300 <sup>F</sup>	70.0–73.0	0.9–1.2	..	..	0.07	remainder	..	..	0.02–0.06	..	..	..	..
G44400 <sup>F</sup>	70.0–73.0	0.9–1.2	..	..	0.07	remainder	..	..	..	0.02–0.10	..	..	..
C44400 <sup>F</sup>	70.0–73.0	0.9–1.2	..	..	0.07	remainder	..	..	..	0.02–0.10	..	..	..
G44500 <sup>F</sup>	70.0–73.0	0.9–1.2	..	..	0.07	remainder	..	..	..	0.02–0.10	..	..	..
C44500 <sup>F</sup>	70.0–73.0	0.9–1.2	..	..	0.07	remainder	..	..	..	0.02–0.10	..	..	..
G60800 <sup>G</sup>	remainder	..	5.0–6.5	..	0.10	..	..	..	..	..	..	..	..
C60800 <sup>A,F</sup>	remainder	..	5.0–6.5	..	0.10	..	..	..	..	..	..	..	..
G66700 <sup>G</sup>	76.0–79.0	..	4.8–2.5	..	0.07	remainder	..	..	0.02–0.35	..	..	..	..
C68700 <sup>A,F</sup>	76.0–79.0	..	1.8–2.5	..	0.07	remainder	..	..	0.02–0.06	..	..	..	..
G70400 <sup>G</sup>	remainder	..	..	–4.8–6.2	0.05	1.3–1.7 max	0.30 to 0.8 max <sup>H</sup>	0.30 to 0.8 max <sup>H</sup>	..	..	..	..	..
C70400 <sup>A,F</sup>	remainder	..	..	4.8–6.2	0.05	1.3–1.7	0.30 to 0.8 max <sup>H</sup>	0.30 to 0.8 max <sup>H</sup>	..	..	..	..	..
G70600 <sup>G</sup>	remainder	..	..	–0.0–11.0	–0.05 <sup>H</sup>	1.0–1.8 max <sup>I</sup>	1.0 max <sup>G</sup>	1.0 max <sup>G</sup>	..	..	..	..	..
C70600 <sup>A,F</sup>	remainder	..	..	9.0–11.0	0.05 <sup>G</sup>	1.0–1.8	1.0 max <sup>G</sup>	1.0 max <sup>G</sup>	..	..	..	..	..
G70620 <sup>G</sup>	86.5 min	..	..	–0.0–11.0	0.02	1.0–1.8	1.0 max <sup>G</sup>	1.0 max <sup>G</sup>	..	..	..	..	0.05 max <sup>D</sup>

- 4.2.1 Heat identification or traceability details.
  - 4.2.2 Tension test (see 9.1),
  - 4.2.23 Relief anneal of U-bent portion of copper-nickel U-bend tubes (see 7.6),
  - 4.2.34 Dual-gage, a schedule of tubes required in dual-gage and length of heavy gage section must be furnished with this option (see ~~5.2.1~~5.2.2 and 12.2.3),
  - 4.2.45 Certification, if required (see 21), and
  - 4.2.56 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~~

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

~~5.2.2.3~~ 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 specified in the ordering information.

~~6.2~~ These specification limits do not preclude the presence of unnamed elements. By agreement between the manufacturer, or supplier, and purchaser, analysis may be required and limits established for elements not specified 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 %.

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
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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 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, 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 Property Requirements—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.

**TABLE 2 Tensile Requirements**

Copper or Copper Alloy UNS No.	Temper Designation		Tensile Strength, min, ksi <sup>B</sup>	Yield Strength, <sup>A</sup> min, ksi <sup>B</sup>	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, <sup>A</sup> 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	...

## 10. Performance Requirements

### 10.1 Expansion Test:

Tube specimens selected for test shall withstand the expansion shown in

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.

## 11. Other Requirements

### 11.1

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

### 10.2 Flattening Test—When:

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.

11.1.1 During 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.

## 11. Other Requirements

11.2.1.1 Mercurous Nitrate Test or Ammonia Vapor Test:

**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