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## Standard Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock<sup>1</sup>

This standard is issued under the fixed designation B 111/B 111M; 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 seamless tube and ferrule stock of copper and various copper alloys up to 3 1/8 in. [80 mm] inclusive, in diameter, for use in surface condensers, evaporators, and heat exchangers. The following coppers and copper alloys are specified:<sup>3</sup> (**Warning**—Mercury is a definite health hazard in use and disposal. (See 12.1.))

| Copper or<br>Copper<br>Alloy<br>UNS No. | Previously<br>Used<br>Designation | Description                             |
|---|-----------------------------------|---|
| C10100                                  | OFE                               | Oxygen-free electronic                  |
| 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                               |
| C28000                                  | ...                               | Muntz Metal                             |
| C44300                                  | ...                               | Admiralty Metals, B, C, and D           |
| C44400                                  | ...                               |   |
| C44500                                  | ...                               |   |
| C60800                                  | ...                               | Aluminum Bronze                         |
| C61300                                  | ...                               | ...                                     |
| C61400                                  | ...                               | Aluminum Bronze, D                      |
| C68700                                  | ...                               | Aluminum Brass, B                       |
| C70400                                  | ...                               | 95-5 Copper-Nickel                      |
| C70600                                  | ...                               | 90-10 Copper-Nickel                     |

<https://standards.iteh.ai/catalog/standards/sist/13a3446c-fad7-403f-b981-b166c1e9519b/astm-b111-b111m-08>

<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-111 in Section II of the Code.

<sup>3</sup> The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix "C" and a suffix "00." The suffix can be used to accommodate composition variations of the base alloy.

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

|        |     |                                   |
|--------|-----|-----------------------------------|
| C70620 | ... | 90-10 Copper-Nickel—Welding Grade |
| C71000 | ... | 80-20 Copper-Nickel               |
| C71500 | ... | 70-30 Copper-Nickel               |
| C71520 | ... | 70-30 Copper-Nickel—Welding Grade |
| C71640 | ... | Copper-nickel-iron-manganese      |
| C72200 | ... | ...                               |

<sup>4</sup> Designations listed in Classification B 224.

1.2 ~~Units—Values~~—The values stated in either ~~inch-pound~~SI units or ~~SI~~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 The following safety hazards caveat pertains only to the test methods portion, Section 19, 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 in the current issue of the *Annual Book of ASTM Standards* form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards*:<sup>4</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](#)
- B 170 [Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes](#)
- B 224 [Classification of Coppers](#)
- 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](#)
- 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 Method for Determination of Copper in Unalloyed Coppers](#)
- E 54 [Test Methods for Chemical Analysis of Special Brasses and Bronzes](#)
- E 62 [Test Methods for Chemical Analysis of Copper and Copper Alloys \(Photometric Methods\)](#)
- E 75 [Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys](#)
- E 76 [Test Methods for Chemical Analysis of Nickel-Copper Alloys](#)
- E 112 [Test Methods for Determining Average Grain Size](#)
- 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](#)
- E 527 [Practice for Numbering Metals and Alloys \(UNS\)](#)—Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

## 3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms relating to copper and copper alloys, refer to Terminology B 846.

3.2 *Definition of Term Specific to This Standard*:

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

## 4. Ordering Information

4.1 Include the following information when placing orders for product under this specification:

- 4.1.1 ASTM Designation and year of approval (for example, ASTM B 111/B 111M – 04),
- 4.1.2 Copper or Copper Alloy UNS Designation (see Table 1),
- 4.1.3 Form (tube or ferrule stock),
- 4.1.4 Temper (see Temper section),
- 4.1.5 Dimensions, outside diameter, and wall thickness, whether minimum or nominal (Dimensions and Permissible Variations Section),
- 4.1.6 Quantity—total weight or total length or number of pieces of each size, and

<sup>4</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<br>Copper<br>Alloy UNS<br>No. | Composition, %         |           |          |                           |                   |            |                      |             |            |            |              |            |   |
|---|------------------------|-----------|----------|---------------------------|-------------------|------------|----------------------|-------------|------------|------------|--------------|------------|---|
|   | Copper <sup>A</sup>    | Tin       | Aluminum | Nickel,<br>incl<br>Cobalt | Lead,<br>max      | Iron       | Zinc                 | Manganese   | Arsenic    | Antimony   | Phosphorus   | Chromium   | Other<br>Named<br>Elements                                |
| C10100                                  | 99.99 min <sup>B</sup> | 0.002 max | ...      | 0.0010 max                | 0.0005 max        | 0.0010 max | 0.0001 max           | 0.00005 max | 0.0005 max | 0.0004 max | 0.0003 max   | 0.0001 max | <sup>C</sup>  |
| C10200 <sup>D</sup>                     | 99.95 min              | ...       | ...      | ...                       | ...               | ...        | ...                  | ...         | ...        | ...        | ...          | ...        | <sup>D</sup>  |
| C10300                                  | 99.95 min <sup>E</sup> | ...       | ...      | ...                       | ...               | ...        | ...                  | ...         | ...        | ...        | 0.001–0.005  | ...        | ...   |
| C10800                                  | 99.95 min <sup>E</sup> | ...       | ...      | ...                       | ...               | ...        | ...                  | ...         | ...        | ...        | 0.005–0.012  | ...        | ...   |
| C12000                                  | 99.90 min              | ...       | ...      | ...                       | ...               | ...        | ...                  | ...         | ...        | ...        | 0.004–0.012  | ...        | ...   |
| C12200                                  | 99.9 min               | ...       | ...      | ...                       | ...               | ...        | ...                  | ...         | ...        | ...        | 0.015–0.040  | ...        | ...   |
| C14200                                  | 99.40 min              | ...       | ...      | ...                       | ...               | ...        | ...                  | ...         | 0.15–0.50  | ...        | 0.015–0.040  | ...        | ...   |
| C19200                                  | 98.5 min               | ...       | ...      | ...                       | ...               | 0.8–1.2    | 0.20 max             | ...         | ...        | ...        | 0.01–0.04    | ...        | ...   |
| C23000                                  | 84.0–86.0              | ...       | ...      | ...                       | 0.05              | 0.05 max   | remainder            | ...         | ...        | ...        | ...          | ...        | ...   |
| C28000                                  | 59.0–63.0              | ...       | ...      | ...                       | 0.30              | 0.07 max   | remainder            | ...         | ...        | ...        | ...          | ...        | ...   |
| C44300                                  | 70.0–73.0              | 0.9–1.2   | ...      | ...                       | 0.07              | 0.06 max   | remainder            | ...         | 0.02–0.06  | ...        | ...          | ...        | ...   |
| C44400                                  | 70.0–73.0              | 0.9–1.2   | ...      | ...                       | 0.07              | 0.06 max   | remainder            | ...         | ...        | 0.02–0.10  | ...          | ...        | ...   |
| C44500                                  | 70.0–73.0              | 0.9–1.2   | ...      | ...                       | 0.07              | 0.06 max   | remainder            | ...         | ...        | ...        | 0.02–0.10    | ...        | ...   |
| C60800                                  | remainder              | ...       | 5.0–6.5  | ...                       | 0.10              | 0.10 max   | ...                  | ...         | 0.02–0.35  | ...        | ...          | ...        | ...   |
| C61300                                  | remainder              | 0.20–0.50 | 6.0–7.5  | 0.15 max                  | 0.01              | 2.0–3.0    | 0.10 max             | 0.20 max    | ...        | ...        | 0.015 max    | ...        | <sup>F,G</sup>  |
| C61400                                  | remainder              | ...       | 6.0–8.0  | ...                       | 0.01              | 1.5–3.5    | 0.20 max             | 1.0 max     | ...        | ...        | 0.015 max    | ...        | ...   |
| C68700                                  | 76.0–79.0              | ...       | 1.8–2.5  | ...                       | 0.07              | 0.06 max   | remainder            | ...         | 0.02–0.06  | ...        | ...          | ...        | ...   |
| C70400                                  | remainder              | ...       | ...      | 4.8–6.2                   | 0.05              | 1.3–1.7    | 1.0 max              | 0.30–0.8    | ...        | ...        | ...          | ...        | ...   |
| C70600                                  | remainder              | ...       | ...      | 9.0–11.0                  | 0.05              | 1.0–1.8    | 1.0 max              | 1.0 max     | ...        | ...        | ...          | ...        | ...   |
| C70620                                  | 86.5 min               | ...       | ...      | 9.0–11.0                  | 0.02              | 1.0–1.8    | 0.50 max             | 1.0 max     | ...        | ...        | 0.02 max     | ...        | C.05 max<br>S.02 max<br><sup>H</sup>                      |
| C71000                                  | remainder              | ...       | ...      | 19.0–23.0                 | 0.05 <sup>H</sup> | 0.50–1.0   | 1.0 max <sup>H</sup> | 1.0 max     | ...        | ...        | <sup>H</sup> | ...        | <sup>H</sup>  |
| C71500                                  | remainder              | ...       | ...      | 29.0–33.0                 | 0.05              | 0.40–1.0   | 1.0 max              | 1.0 max     | ...        | ...        | ...          | ...        | ...   |
| C71520                                  | 65.0 min               | ...       | ...      | 29.0–33.0                 | 0.02              | 0.40–1.0   | 0.50 max             | 1.0 max     | ...        | ...        | 0.02 max     | ...        | C.05 max<br>S.02 max<br>C.06 max<br>S.03 max <sup>H</sup> |
| C71640                                  | remainder              | ...       | ...      | 29.0–32.0                 | 0.05 <sup>H</sup> | 1.7–2.3    | 1.0 max <sup>H</sup> | 1.5–2.5     | ...        | ...        | <sup>H</sup> | ...        | C.06 max<br>S.03 max <sup>H</sup>                         |
| C72200                                  | remainder              | ...       | ...      | 15.0–18.0                 | 0.05 <sup>H</sup> | 0.50–1.0   | 1.0 max <sup>H</sup> | 1.0 max     | ...        | ...        | <sup>H</sup> | 0.30–0.70  | Si.03 max<br>Ti.03 max <sup>H</sup>                       |

<sup>A</sup> Copper (including silver).

<sup>B</sup> This value is exclusive of silver and shall be determined by difference of “impurity total” from 100 %. “Impurity total” is defined as the sum of sulfur, silver, lead, tin, bismuth, arsenic, antimony, iron, nickel, mercury, zinc, phosphorus, selenium, tellurium, manganese, cadmium, and oxygen present in the sample.

<sup>C</sup> Impurity maximums in ppm for C10100 shall be: antimony 4, arsenic 5, bismuth 1, cadmium 1, iron 10, lead 5, manganese 0.5, mercury 1, nickel 10, oxygen 5, phosphorus 3, selenium 3, silver 25, sulfur 15, tellurium 2, tin 2, and zinc 1.

<sup>D</sup> Oxygen in C10200 shall be 10 ppm max.

<sup>E</sup> Copper plus sum of named elements shall be 99.95 % min.

<sup>F</sup> Silicon shall be 0.10 % max.

<sup>G</sup> When the product is for subsequent welding applications and is so specified by the purchaser, chromium shall be 0.05 % max, cadmium 0.05 % max, zinc 0.05 % max, and zirconium 0.05 % max.

<sup>H</sup> 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.

4.1.7 If product is purchased for agencies of the U.S. Government (see the Supplementary Requirements Section).

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

4.2.1 Tension Test required per ASME Boiler and Pressure Vessel Code, Mechanical Properties section.

4.2.2 Pressure test as an alternative to eddy current test (Nondestructive Testing Section).

4.2.3 If the cut ends of the tubes do not need to be deburred (Workmanship, Finish, and Appearance section).

4.2.4 If the product is to be subsequently welded (Table 1, Footnotes G and H).

4.2.5 Residual Stress Test—Ammonia Vapor Test or Mercurous Nitrate Test (Performance Requirements Section).

4.2.6 For Ammonia Vapor Test, risk level (pH value) if other than 10.

4.2.7 Heat identification or traceability details (Number of tests and Retests section).

4.2.8 Certification (Certification Section).

4.2.9 Mill Test Report (Mill Test Report Section).

4.2.10 If a subsequent thermal treatment after straightening is required (Temper section).

## 5. Materials and Manufacture

5.1 *Materials*—The material shall be of such quality and purity that the finished product shall have the properties and characteristics prescribed in this specification.

5.2 *Manufacture*—The product shall be produced by processes such as casting, extrusion, drawing, annealing, straightening, trimming, and other processes which may produce a seamless tube in the specified condition.

## 6. Chemical Composition

6.1 The product shall conform to the chemical requirements specified in Table 1.

6.2 These composition limits do not preclude the presence of other elements. Limits for unnamed elements may be established

by agreement between manufacturer or supplier and purchaser.

6.2.1 *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.

6.2.2 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 %.

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

| Copper Alloy<br>UNS No. | Copper Plus Named<br>Elements, % min |
|-------------------------|--------------------------------------|
| C60800                  | 99.5                                 |
| C61300                  | 99.8                                 |
| C61400                  | 99.5                                 |
| C70400                  | 99.5                                 |
| C70600 & C70620         | 99.5                                 |
| C71000                  | 99.5                                 |
| C71500 & C71520         | 99.5                                 |
| C71640                  | 99.5                                 |
| C72200                  | 99.8                                 |

6.2.3 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 %.

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

| Copper Alloy<br>UNS No. | Copper Plus Named<br>Elements, % min |
|-------------------------|--------------------------------------|
| C23000                  | 99.8                                 |
| C28000                  | 99.7                                 |
| C44300                  | 99.6                                 |
| C44400                  | 99.6                                 |
| C44500                  | 99.6                                 |
| C68700                  | 99.5                                 |

## 7. Temper

7.1 Tubes of Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, C68700, and C71000 shall be furnished in the annealed (O61) temper unless otherwise specified on the purchase order.

7.2 Tubes of Copper Alloy UNS Nos. C71500, C71520, and C71640 shall be supplied in one of the following tempers as specified: (1) annealed (O61) or (2) drawn, and stress-relieved (HR50).

7.3 Tubes of Copper Alloy UNS Nos. C10100, C10200, C10300, C10800, C12000, C12200, and C14200 shall be supplied in any one of the following tempers, one of which shall be specified: (1) light-drawn (H55), (2) hard-drawn (H80), or (3) hard drawn and end annealed (HE80).

7.4 Tubes of Copper Alloy UNS No. C19200 shall be supplied in any one of the following tempers, one of which shall be specified: (1) annealed (O61), (2) light-drawn (H55), (3) hard-drawn (H80), or (4) hard-drawn, and end-annealed (HE80).

7.5 Tubes of Copper Alloy UNS Nos. C70400, C70600, C70620, and C72200 may be supplied in either light-drawn (H55) or annealed (O61) temper.

7.6 Tubes for ferrule stock shall be annealed sufficiently to be fully recrystallized.

7.7 *Optional Post-Straightening Thermal Treatment* —Some tubes, when subjected to aggressive environments, may have the potential for stress-corrosion cracking failure due to the residual stresses induced during straightening processing. For such applications, it is suggested that tubes of Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, 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.

## 8. Mechanical Properties

8.1 Material specified to meet the requirements of the *ASME Boiler and Pressure Vessel Code* shall have tensile properties as prescribed in Table 2 or Table 3.

## 9. Grain Size for Annealed Tempers

9.1 Grain size shall be a standard requirement for all product in the annealed (O61) temper.

9.1.1 Samples of annealed-temper tubes selected for test shall be subjected to microscopical examination per Test Methods E 112 at a magnification of 75 diameters and shall show uniform and complete recrystallization.

9.1.2 Products other than of Copper Alloy UNS Nos. C19200 and C28000 shall have an average grain size within the limits of 0.010 to 0.045 mm. These requirements do not apply to tubes of light-drawn (H55), hard-drawn (H80), hard-drawn and end-annealed (HE80), or drawn and stress-relieved tempers (HR50).



TABLE 2 Tensile Requirements—Inch-Pound Values

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

| Copper or Copper Alloy UNS No.                         | Temper Designation |                           | Tensile Strength,<br>min ksi <sup>A</sup> | Yield Strength, <sup>B</sup><br>min ksi <sup>A</sup> | Elongation in 2 in.,<br>min % |
|--|--------------------|---------------------------|---|--|-------------------------------|
|  | Standard           | Former                    |   |  |                               |
| C10100, C10200, C10300, C10800, C12000, C12200, C14200 | H55                | light-drawn               | 36  | 30   | ...                           |
| C10100, C10200, C10300, C10800, C12000, C12200, C14200 | H80                | hard-drawn                | 45  | 40   | ...                           |
| C19200   | H55                | light-drawn               | 40  | 35   | ...                           |
| C19200   | H80                | hard-drawn                | 48  | 43   | ...                           |
| C19200   | O61                | annealed                  | 38  | 12   | ...                           |
| C23000   | O61                | annealed                  | 40  | 12   | ...                           |
| C28000   | O61                | annealed                  | 50  | 20   | ...                           |
| C44300, C44400, C44500                                 | O61                | annealed                  | 45  | 15   | ...                           |
| C60800   | O61                | annealed                  | 50  | 19   | ...                           |
| C61300, C61400   | O61                | annealed                  | 70  | 30   | ...                           |
| 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, C70520   | O61                | annealed                  | 52  | 18   | ...                           |
| C71500, C70520   | HR50               | drawn and stress-relieved | 72  | 50   | 12                            |
| Wall thicknesses up to 0.048 in., incl                 | HR50               | drawn and stress-relieved | 72  | 50   | 15                            |
| Wall thicknesses over 0.048 in.                        | O61                | annealed                  | 63  | 25   | ...                           |
| C71640   | HR50               | drawn and stress relieved | 81  | 58   | ...                           |
| C72200   | O61                | annealed                  | 45  | 16   | ...                           |
| C72200   | H55                | light-drawn               | 50  | 30   | ...                           |

<sup>A</sup> ksi = 1000 psi.<sup>B</sup> At 0.5 % extension under load.

TABLE 3 Tensile Requirements—SI Values

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

| Copper or Copper Alloy UNS No.                         | Temper Designation |                           | Tensile Strength,<br>min MPa | Yield Strength, <sup>A</sup><br>min MPa | Elongation in 50 mm,<br>min % |
|--|--------------------|---------------------------|------------------------------|---|-------------------------------|
|  | Standard           | Former                    |                              |   |                               |
| C10100, C10200, C10300, C10800, C12000, C12200, C14200 | H55                | light-drawn               | 250                          | 205                                     | ...                           |
| C10100, C10200, C10300, C10800, C12000, C12200, C14200 | H80                | hard-drawn                | 310                          | 275                                     | ...                           |
| C19200   | H55                | light-drawn               | 275                          | 240                                     | ...                           |
| C19200   | H80                | hard-drawn                | 330                          | 295                                     | ...                           |
| C19200   | O61                | annealed                  | 260                          | 85                                      | ...                           |
| C23000   | O61                | annealed                  | 275                          | 85                                      | ...                           |
| C28000   | O61                | annealed                  | 345                          | 140                                     | ...                           |
| C44300, C44400, C44500                                 | O61                | annealed                  | 310                          | 105                                     | ...                           |
| C60800   | O61                | annealed                  | 345                          | 130                                     | ...                           |
| C61300, C61400   | O61                | annealed                  | 480                          | 205                                     | ...                           |
| 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                                     | ...                           |
| C71500, C71520:  | HR50               | drawn and stress-relieved | 495                          | 345                                     | 12                            |
| Wall thicknesses up to 1.2 mm incl                     | HR50               | drawn and stress-relieved | 495                          | 345                                     | 15                            |
| Wall thicknesses over 1.2 mm.                          | O61                | annealed                  | 435                          | 170                                     | ...                           |
| C71640   | HR50               | drawn and stress relieved | 560                          | 400                                     | ...                           |
| C72200   | O61                | annealed                  | 310                          | 110                                     | ...                           |
| C72200   | H55                | light-drawn               | 345                          | 310                                     | ...                           |

<sup>A</sup> At 0.5 % extension under load.

## 10. Expansion Test

10.1 Tube specimens selected for test shall withstand the expansion shown in Table 4 when expanded in accordance with Test Method B 153. The expanded tube shall show no cracking or rupture visible to the unaided eye.

10.2 Hard-drawn tubes not end annealed are not subject to this test. When tubes are specified end annealed, this test is required and shall be performed on the annealed ends of the sampled tubes.



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  |  |    |
|                    |                             | C28000   | 15  |  |    |
|                    |                             | C44300, C44400, C44500                                 | 20  |  |    |
|                    |                             | C60800   | 20  |  |    |
|                    |                             | C61300, C61400   | 20  |  |    |
|                    |                             | C68700   | 20  |  |    |
|                    |                             | C70400   | 30  |  |    |
|                    |                             | C70600, C70620   | 30  |  |    |
|                    |                             | C71000   | 30  |  |    |
|                    |                             | C71500, C71520   | 30  |  |    |
|                    |                             | C71640   | 30  |  |    |
|                    |                             | C72200   | 30  |  |    |
|                    |                             | H55  | light-drawn   | C10100, C10200, C10300, C10800, C12000, C12200 | 20 |
|                    |                             |  |   | C14200   | 20 |
|                    |                             |  |   | C19200   | 20 |
| C70400             | 20                          |  |   |  |    |
| C70600, C70620     | 20                          |  |   |  |    |
| C72200             | 20                          |  |   |  |    |
| HR50               | drawn and stress relieved   | C71500, C71520   | 20  |  |    |
|                    |                             | C71640   | 20  |  |    |
| ...                | hard-drawn and end annealed | C10100, C10200, C10300, C10800, C12000, C12200, C14200 | 30  |  |    |

10.3 Tubes for ferrule stock are not subject to the expansion test.

11. Flattening Test

11.1 Test Method—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. 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 of the test specimen shall be inspected for surface defects.

11.2 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.

11.3 Tubes for ferrule stock are not subject to flattening test.

12. Residual Stress Test

12.1 A residual stress test is required to be performed only for Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, and C68700. A residual stress test, when specified in the purchase order, is required only for Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, and C68700 and when not supplied in an annealed temper.

12.2 Unless otherwise specified, the producer shall have the option of testing the product to either the mercurous nitrate test, Test Method B 154, or the ammonia vapor test, Test Method B 858, as prescribed below.

12.2.1 Mercurous Nitrate Test:

12.2.1.1 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.

12.2.1.2 The test specimens, cut 6 in. [150 mm] in length, shall withstand without cracking, an immersion in the standard mercurous nitrate solution prescribed in Test Method B 154. The test specimen shall include the finished tube end.

12.2.2 Ammonia Vapor Test:

12.2.2.1 The test specimens, cut 6 in. [150 mm] in length, shall withstand without cracking, the ammonia vapor test as prescribed in Test Method B 858. For the purposes of this specification, unless otherwise agreed between purchaser and supplier, the risk level identified in the Annex of Method B 858, shall be specified as risk level (pH value) of 10.

13. Nondestructive Testing

13.1 Each tube shall be subjected to the eddy-current test in 13.1.1. Tubes may be tested in the final drawn, annealed, or heat-treated temper or in the drawn temper before the final anneal or heat treatment unless otherwise agreed upon by the 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 E 243.

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 Tables 5 and 6, and Tables 7 and 8, respectively.