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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Specification for Welded Copper and Copper-Alloy Heat Exchanger Tube¹

This standard is issued under the fixed designation B 543; 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 covers welded tube of copper and various copper alloys up to 3½ in., inclusive, in diameter, for use in surface condensers, evaporators, heat exchangers, and general engineering applications. Tubes for this application are normally made of the following coppers or copper alloys:²

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

^A Designation listed in Classification B 224.

1.2 **Warning**—Mercury is a definite health hazard in use and disposal. (See 14.1.)

NOTE 1—A complete metric companion to Specification B 543 has been developed—B 543M; therefore, no metric equivalents are presented in this specification.

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:*

B 153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing³

¹ This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.04 on Pipe and Tube.

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² New designation established in accordance with Practice E 527. In the new UNS system, the designations for copper alloys are simply expansions of the present standard designations by a prefix “C” and a suffix “00.”

³ *Annual Book of ASTM Standards*, Vol 02.01.

B 154 Test Method for Mercurous Nitrate Test for Copper and Copper Alloys³

B 224 Classification of Coppers³

E 8 Test Methods for Tension Testing of Metallic Materials⁴

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications⁵

E 53 Test Methods for Chemical Analysis of Copper⁶

E 54 Test Methods for Chemical Analysis of Special Brasses and Bronzes⁶

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition⁶

E 62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods)⁶

E 75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys⁶

E 112 Test Methods for Determining Average Grain Size⁴

E 243 Practice for Electromagnetic (Eddy-Current) Examination of Copper and Copper-Alloy Tubes⁷

E 478 Test Methods for Chemical Analysis of Copper Alloys⁸

E 527 Practice for Numbering Metals and Alloys (UNS)⁹

3. Terminology

3.1 *Description of Term Specific to This Standard:*

3.1.1 *capable of*—as used in this specification, 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. Types of Welded Tube

4.1 *Forge-Welded Tube* manufactured as described in 6.2.1, 6.2.1.1, and 6.2.1.2.

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

4.1.2 *Welded and Annealed Tube*—Forge-welded tube with internal and external flash removed, that has been annealed to

⁴ *Annual Book of ASTM Standards*, Vol 03.01.

⁵ *Annual Book of ASTM Standards*, Vol 14.02.

⁶ *Annual Book of ASTM Standards*, Vol 03.05.

⁷ *Annual Book of ASTM Standards*, Vol 03.03.

⁸ *Annual Book of ASTM Standards*, Vol 03.06.

⁹ *Annual Book of ASTM Standards*, Vol 01.01.

produce a uniform grain size appropriate to the specified annealed temper.

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

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

4.2 *Fusion-Welded Tube* manufactured as described in 6.2.2.

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

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

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

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

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

5. Ordering Information

5.1 Orders for material under this specification shall include the following information:

5.1.1 Quantity of each size (number of pieces and number of feet),

5.1.2 Material (Sections 1, 6, and 7),

5.1.3 Temper (Section 8),

5.1.3.1 If tension tests are required (Section 9),

5.1.4 Whether a pressure test is to be used instead of the eddy-current test (see 15.1),

5.1.5 Dimensions, the diameter, wall thickness, whether minimum or nominal wall, and length, (Section 16),

5.1.6 Type of welded tube (Section 4),

5.1.7 Whether cut ends of the tube are to be deburred, chamfered, or otherwise treated (see 17.1),

5.1.8 If the product is to be subsequently welded (see Table 1 and Footnote C),

5.1.9 Specification number and year of issue,

5.1.10 Certification, if required (Section 24), and

5.1.11 Mill test report, if required (Section 26).

5.2 In addition, when material is purchased for agencies of the U.S. Government, it shall conform to the Supplementary Requirements as defined herein when specified in the contract or purchase order.

6. Materials and Manufacture

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

6.2 Welded tube shall be made of clean strip in either cold-rolled or annealed tempers. The strip shall be formed into a tubular shape on a suitable forming mill.

6.2.1 For forge-welded tube, the edges of the strip shall be heated to the required welding temperature, usually by high-frequency electric current, and be pressed firmly together causing a forge-type joint to be formed with internal and external flash or bead.

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

6.2.1.2 The internal flash in forge-welded tube shall be removed to the extent that it shall not exceed 0.006 in. in height or 10 % of the nominal wall thickness, whichever is greater.

6.2.2 For fusion-welded tube, the edges of the strip shall be brought together and welded, usually by a GTAW welding process, without the addition of filler metal, causing a fusion-type joint to be formed with no internal or external flash or bead removal necessary.

6.2.3 Tube type, 4.3, fully finished tube, may be welded and subsequently processed by any method that would produce a tube suitable for subsequent cold-drawing and annealing.

TABLE 1 Chemical Requirements

Copper or Copper Al- loy UNS No.	Composition, %											
	Copper ^A	Nickel incl Cobalt	Lead, max	Iron	Zinc	Man- ganese	Aluminum	Phosphorus	Tin	Antimony	Arsenic	Other Ele- ments
C10800	99.95 ^B min	...	...	...	...	...	...	0.005–0.012	...	...	...	...
C12200	99.9 min	...	...	...	...	...	...	0.015–0.040	...	...	...	...
C19400	97.0–97.8	...	0.03	2.1–2.6	0.05–0.20	...	...	0.015–0.15	...	...	...	...
C23000	84.0–86.0	...	0.05	0.05 max	remainder	...	...	...	...	...	...	...
C44300	70.0–73.0	...	0.07	0.06 max	remainder	...	...	...	0.8–1.2	...	0.02–0.06	...
C44400	70.0–73.0	...	0.07	0.06 max	remainder	...	...	...	0.8–1.2	0.02–0.10	...	...
C44500	70.0–73.0	...	0.07	0.06 max	remainder	...	...	0.02–0.10	0.8–1.2	...	...	...
C68700	76.0–79.0	...	0.07	0.06 max	remainder	...	1.8–2.5	...	...	...	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 ^C	1.0–1.8	1.0 max ^C	1.0 max	...	^C	...	...	...	^C
C71000	remainder	19.0–23.0	0.05 ^C	0.50–1.0	1.0 max ^C	1.0 max	...	^C	...	...	...	^C
C71500	remainder	29.0–33.0	0.05 ^C	0.40–1.0	1.0 max ^C	1.0 max	...	^C	...	...	...	^C
C71640	remainder	29.0–32.0	0.05 ^C	1.7–2.3	1.0 max ^C	1.5–2.5	...	^C	...	...	...	^C
C72200 ^D	remainder	15.0–18.0	0.05 ^C	0.5–1.0	1.0 max ^C	1.0 max	...	^C	...	...	...	^{C,D}

^A Silver counting as copper.

^B Copper + silver + phosphorus.

^C 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.

^D Chromium 0.30 to 0.70.

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

NOTE 2—The term “unaided eye” as used herein permits the use of corrective spectacles necessary to obtain normal vision.

7. Chemical Composition

7.1 The material shall conform to the requirements specified in Table 1.

7.2 These specification limits do not preclude the presence of other elements. Limits for unnamed elements may be established by agreement between manufacturer or supplier and purchaser.

7.2.1 For Copper Alloy UNS No. C19400, 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.

7.2.2 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 %.

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

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

7.2.3 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 %.

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

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

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

8. Temper

8.1 Tube tempers shall be designated as follows:

8.1.1 Annealed tempers,

8.1.1.1 Welded and annealed,

8.1.1.2 Fully finished—annealed,

8.1.2 Light cold worked tempers,

8.1.2.1 As-welded from annealed strip,

8.1.2.2 As-welded, light cold worked, and

8.1.2.3 Fully finished—light drawn.

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

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

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

NOTE 3—Some tubes, when subjected to aggressive environments, may be subject to stress-corrosion cracking failure because of the residual tensile stresses developed in straightening. For such applications, it is suggested that tubes of Copper Alloy UNS Nos. C23000, C44300, C44400, C44500, and C68700 be subjected to a stress relieving thermal treatment subsequent to straightening. If required, this must be specified on the purchase order or contract. Tolerances for roundness and length, and the condition of straightness, for tube so ordered, shall be to the requirements agreed upon between the manufacturer and the purchaser.

NOTE 4—The temper of 8.1.2.2 is to permit the production of a light cold-worked as-welded tube by means other than the use of annealed strip. Some of these, for example, are the use of annealed to temper strip, the use of lightly cold-rolled strip, and the use of cold-rolled strip and wherein the resulting tube is subsequently relief annealed.

9. Mechanical Properties

9.1 Tube specified to meet strength requirements shall have tensile properties as prescribed in Table 2.

10. Microscopical Examination

10.1 Samples of welded and annealed tube and of fully finished annealed tube shall be subjected to microscopical examination at a magnification of 75 diameters.

10.1.1 Forge-welded and annealed tube shall have a completely recrystallized grain structure, and the weld zone shall have a structure typical of hot-forged welds.

10.1.2 Fusion-welded and annealed tube shall have a completely recrystallized grain structure, and the weld zone shall have a structure typical of a fusion weld.

10.1.3 Fully finished and annealed tube shall have a completely recrystallized structure typical of the metal when cold-worked and annealed, including the weld zone.

10.2 Samples selected for test shall be examined microscopically at a magnification of 75 diameters to establish that the weld interface is metallurgically sound.

11. Expansion Test

11.1 Tubes supplied in the annealed temper (8.1.1) and the light cold-worked temper (8.1.2) and tubes supplied in the stress relieved condition shall pass the expansion test as specified in 11.2.

11.2 Tube specimens selected for test shall withstand the expansion shown in Table 3 when expanded in accordance with Test Method B 153. The expanded tube shall show no cracking or rupture visible to the unaided eye (see Note 2).

12. Flattening Test

12.1 Test specimens at least 4 ft in length shall be flattened on different elements throughout the length remaining after specimens for the expansion and metallographic tests have been taken. Each element shall be slowly flattened by one stroke of a press. The term “flattened” shall be interpreted as follows: A micrometer caliper set at three times the wall thickness shall pass over the tube freely throughout the flattened part except at the points where the change in element of flattening takes place. The flattened elements shall not show cracking or rupture visible to the unaided eye (Note 2). The weld when visible or identifiable shall be placed in the position of maximum bend on one half of the flattened elements. When tubes are specified in a temper other than annealed (8.1.1), this test is required and may be made on annealed specimens.