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Standard Specification for Copper-Alloy Plate and Sheet for Pressure Vessels, Condensers, and Heat Exchangers[1]

This standard is issued under the fixed designation B171/B171M; 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 U.S. Department of Defense.

1. Scope*

1.1 This specification[2] establishes the requirements for copper-alloy plate, sheet, and circles cut from plate and sheet for pressure vessels, condensers, and heat exchangers. The following alloys are covered:

Copper Alloy	Previously Used Designation
C36500	Leaded Muntz Metal
C44300	Admiralty, Arsenical
C44400	Admiralty, Antimonial
C44500	Admiralty, Phosphorized
C46400	Naval Brass, Uninhibited
C46500	Naval Brass, Arsenical
C61300	Aluminum Bronze
C61400	Aluminum Bronze D
C63000	10 % Aluminum-Nickel Bronze
C63200	9 % Aluminum-Nickel Bronze
C70600	90-10 Copper Nickel
~~C70620~~	~~90-10 Copper Nickel (modified for welding)~~
C70620	90-10 Copper Nickel-(modified for welding)
C71500	70-30 Copper Nickel
C71520	70-30 Copper Nickel-(modified for welding)
C72200	. . .

1.2 *Units*—~~Units—The~~The values stated in either ~~SI~~inch-pound units or ~~inch-pound~~SI 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 international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

B248 Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar

B248M Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar (Metric)

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

B846 Terminology for Copper and Copper Alloys

E8/E8M Test Methods for Tension Testing of Metallic Materials

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

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[1] This specification is under the jurisdiction of ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.01 on Plate, Sheet, and Strip.

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[2] For *ASME Boiler and Pressure Vessel Code* applications, see related Specification SB-171 in Section II of that Code.

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

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

E54 Test Methods for Chemical Analysis of Special Brasses and Bronzes (Withdrawn 2002)[4]
E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)[4]
E255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition
E478 Test Methods for Chemical Analysis of Copper Alloys
E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

3. Terminology

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

4. Ordering Information

4.1 Include the following ~~information~~ specified choices when placing orders for product under this specification, as applicable:
4.1.1 ASTM designation and year of ~~issue,~~issue;
4.1.2 Whether inch-pound or SI units are applicable (see 1.2~~),~~);
4.1.3 Copper ~~Alloy~~[Alloy] UNS. No. (see Section 6, Table 1~~),~~);
4.1.4 Whether the alloy ordered will be used in applications requiring it to be welded (see Table 1, footnotes ~~B~~C and ~~C~~D for UNS Nos. C61300 and C72200, respectively, and UNS Nos. C70620 and C71520 in place of UNS Nos. C70600 and ~~C71500),~~C71500);
4.1.5 Whether plate is to be machined (see 9.1.3~~),~~);
4.1.6 How tolerance is specified (Table 2 ~~Footnote A),~~, footnote A); and
~~4.1.7 Certification, if required (Section 17),~~
4.1.7 Weight (total for each ~~size),~~size).
~~4.1.9 Mill test report, if required (Section 18),~~
~~4.1.10 Special marking, if required (Section 19), and~~

TABLE 1 Chemical Requirements

Copper Alloy UNS No.[A]	Composition, % max (Unless Shown as a Range)									
	Copper, incl Silver	Tin	Nickel, incl Cobalt	Manganese, max	Lead	Iron	Zinc	Aluminum	Chromium	Other Named Elements
C36500	58.0-61.0[B]	0.25	. . .	. . .	0.25-0.7	0.15	remainder	. . .	. . .	. . .
C44300	70.0-73.0[B]	0.8-1.2	. . .	. . .	0.07	0.06	remainder	. . .	. . .	0.02-0.06 As
C44400	70.0-73.0[B]	0.8-1.2	. . .	. . .	0.07	0.06	remainder	. . .	. . .	0.02-0.10 Sb
C44500	70.0-73.0[B]	0.8-1.2	. . .	. . .	0.07	0.06	remainder	. . .	. . .	0.02-0.10 P
C46400	59.0-62.0[B]	0.50-1.0	. . .	. . .	0.20	0.10	remainder	. . .	. . .	. . .
C46500	59.0-62.0[B]	0.50-1.0	. . .	. . .	0.20	0.10	remainder	. . .	. . .	0.02-0.06 As
~~C61300[B]~~	~~remainder~~	~~0.20-0.50~~	~~0.15~~	~~0.20~~	~~0.01~~	~~2.0-3.0~~	~~0.10[C]~~	~~6.0-7.5~~	~~. . .~~	~~0.10 Si~~
C61300[C]	remainder	0.20-0.50	0.15	0.20	0.01	2.0-3.0	0.10[D]	6.0-7.5	. . .	0.10 Si 0.015 P
C61400	remainder	. . .	. . .	1.0	0.01	1.5-3.5	0.20	6.0-8.0	. . .	0.015 P
C63000	remainder	0.20	4.0-5.5	1.5	. . .	2.0-4.0	0.30	9.0-11.0	. . .	0.25 Si
~~C63200~~	~~remainder~~	~~. . .~~	~~4.0-4.8[D]~~	~~1.2-2.0~~	~~0.02~~	~~3.5-4.3[D]~~	~~. . .~~	~~8.7-9.5~~	~~. . .~~	~~0.10 Si~~
C63200	remainder	. . .	4.0-4.8[E]	1.2-2.0	0.02	3.5-4.3[E]	. . .	8.7-9.5	. . .	0.10 Si
~~C70600~~	~~remainder~~	~~. . .~~	~~9.0-11.0~~	~~1.0~~	~~0.05[C]~~	~~1.0-1.8~~	~~1.0[C]~~	~~. . .~~	~~. . .~~	
C70600	remainder	. . .	9.0-11.0	1.0	0.05[D]	1.0-1.8	1.0[D]	. . .	. . .	
C70620	86.5 min	. . .	9.0-11.0	1.0	0.02	1.0-1.8	0.50	. . .	. . .	0.05 C 0.02 P 0.02 S
~~C71500~~	~~remainder~~	~~. . .~~	~~29.0-33.0~~	~~1.0~~	~~0.05[C]~~	~~0.40-1.0~~	~~1.0[C]~~	~~. . .~~	~~. . .~~	
C71500	remainder	. . .	29.0-33.0	1.0	0.05[D]	0.40-1.0	1.0[D]	. . .	. . .	
C71520	65.0 min	. . .	29.0-33.0	1.0	0.02	0.40-1.0	0.50	. . .	. . .	0.05 C 0.02 P 0.02 S
~~C72200~~	~~remainder~~	~~. . .~~	~~15.0-18.0~~	~~1.0~~	~~0.05[C]~~	~~0.50-1.0~~	~~1.0[C]~~	~~. . .~~	~~†0.30-0.70~~	~~0.03 Si~~
C72200	remainder	. . .	15.0-18.0	1.0	0.05[D]	0.50-1.0	1.0[D]	. . .	0.30-0.70	0.03 Si 0.03 Ti C D

[A] Designation established in accordance with Practice E527.
[B] Not including silver.
[C] 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, zirconium 0.05 % max and zinc 0.05 % max.
[D] When the product is for subsequent welding applications, and is 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.
[E] Iron content shall not exceed the nickel content.
~~† Editorially corrected.~~

[4] The last approved version of this historical standard is referenced on www.astm.org.

TABLE 2 Thickness Tolerances

Thickness, in. [mm]	Thickness Tolerances, Plus and Minus,[A,B] in. [mm] for Diameters or Widths			
	36 in. [1000 mm] or Under, incl	Over 36 to 60 in. [1000 to 1500 mm], incl	Over 60 to 96 in. [1500 to 2500 mm], incl	Over 96 to 132 in. [2500 to 3500 mm], incl
Over 0.125 to 0.250 [3.0 to 6.0 mm], incl	0.010 [0.25]	0.012 [0.30]	0.022 [0.56]	0.028 [0.71]
Over 0.250 to 0.500 [6.0 to 12.0 mm], incl	0.025 [0.64]	0.027 [0.69]	0.029 [0.74]	0.031 [0.79]
Over 0.500 to 0.750 [12.0 to 19.0 mm], incl	0.028 [0.71]	0.030 [0.76]	0.032 [0.81]	0.035 [0.89]
Over 0.750 to 1.000 [19.0 to 25.0 mm], incl	0.033 [0.84]	0.035 [0.89]	0.037 [0.94]	0.040 [1.0]
Over 1.000 to 1.500 [25.0 to 38.0], incl	0.038 [0.97]	0.040 [1.0]	0.042 [1.1]	0.045 [1.1]
Over 1.500 to 1.750 [38.0 to 44.0 mm], incl	0.043 [1.1]	0.045 [1.1]	0.047 [1.2]	0.050 [1.3]
Over 1.750 to 2.000 [44.0 to 50.0 mm], incl	0.050 [1.3]	0.055 [1.4]	0.062 [1.6]	0.065 [1.7]
Over 2.000 to 5.000 [50.0 to 127 mm], incl	0.058 [1.5]	0.062 [1.6]	0.065 [1.7]	. . .

[A] When tolerances are specified as all plus or all minus, double the values given.
[B] See 9.1.2 for specific alloys with a difference tolerance.

~~4.1.11 Whether 0.2 yield offset strength is required.~~

4.2 The following options are available but may not be included unless specified at the time of placing the order, when required.
4.2.1 Certification, if required (Section 17);
4.2.2 Test report, if required (Section 18);
4.2.3 Special marking, if required (Section 20);
4.2.4 Whether yield strength 0.2 % offset is required;
4.2.5 Heat identification or traceability details (5.1.2); and
4.2.6 Source inspection (15.2).

5. Materials and Manufacture

5.1 ~~*Material—*~~*Material:* ~~The material and manufacture shall be cast cake of the Copper Alloy UNS No. specified in the purchase order and shall be of such shape and soundness so as to be suitable for processing into the final product.~~

5.1.1 The material of manufacture shall be cast cake of the Copper Alloy UNS No. specified in the purchase order of such purity and soundness as to be suitable for processing into the products prescribed herein.

5.1.2 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 castings into wrought products, it is not always practical to identify a specific casting analysis with a specific quantity of finished material.

5.2 ~~*Manufacture—*~~*Manufacture:* ~~The product shall be manufactured by hot rolling or forging and finished by such cold working and annealing as may be necessary to achieve the required dimensions and properties.~~

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 The product shall be hot or cold worked to the finished size, and subsequently annealed, when required, to meet the temper properties specified.

6. Chemical Composition

6.1 The materials shall conform to the chemical compositional requirements specified in Table 1 for the copper ~~alloy~~[alloy] UNS designations specified in the ordering ~~information.~~information.

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

6.3 For the alloys listed below, ~~depending on analytical methodology,~~ zinc is listed as "remainder," either copper or zinc, respectively, 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 as shown below:

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C36500	99.6
C44300	99.6
C44400	99.6
C44500	99.6
C46400	99.6
C46500	99.6

6.3.1 For the alloys listed below, copper may be taken as the difference between the sum of all the elements and 100 %. When all of the elements in Table 1 are analyzed, their sum shall be as shown below:

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C61300	99.8
C61400	99.5
C63000	99.5
C63200	99.5
C70600	99.5
C70620	99.5
C71520	99.5
C71500	99.5
C72200	99.8

7. Temper

7.1 ~~Tempers available under this specification, and as described in Classification~~The standard tempers for products described in this ~~B601, are As Hot Rolled (M20), Hot Rolled and Annealed (O25), Hot Forged and Annealed (O20), and As Hot Forged-Air Cooled (M10) as~~ specification are given in Table 3.

7.1.1 As Hot Rolled Temper M20.

7.1.2 As Hot Forged-Air Cooled M10.

7.1.3 Hot Forged and Annealed O20.

7.1.4 Hot Rolled and Annealed O25.

7.1.5 Products manufactured for *ASME Boiler and Pressure Vessel Code* applications must be certified to the O25 or O20 temper.

7.1.6 Products manufactured for other than *ASME Boiler and Pressure Vessel Code* applications may be produced in either the M20, M10, O20, or O25 temper.

8. Mechanical Property Requirements

8.1 *Tensile Strength* ~~*Requirements :*~~ *Requirements:*

8.1.1 Product furnished under this specification shall conform to the ~~tensile~~mechanical property requirements prescribed in Table 3, when tested in accordance with Test ~~Method~~Methods E8/E8M.

8.1.2 Acceptance or rejection shall be based upon the 8.1.1 mechanical properties.

9. Dimensions, Mass, and Permissible Variations

9.1 *Thickness:*

9.1.1 The thickness tolerances for plates of Copper Alloy UNS Nos. C36500, C44300, C44400, C44500, C46400, and C46500 shall be as prescribed in Table 2.

TABLE 3 Tensile Requirements—M20, M10, O20, and O25 Tempers

Copper Alloy UNS No.	Thickness, in. [mm]	Tensile Strength, min, ksi[A] [MPa]	Yield Strength,[B] min, ksi[A] [MPa]	Yield Strength[C] 0.2 % Offset, min, ksi[A] [MPa]	Elongation in 2 in. [50.0 mm], min, %
	2 [50.0] and under	50 [345]	20 [140]	20 [140]	35 [35]
C36500	over 2 to 3.5 [50.0 to 100.0], incl	45 [310]	15 [105]	15 [105]	35 [35]
	over 3.5 to 5 [100.0 to 140.0], incl	40 [275]	12 [85]	12 [85]	35 [35]
C44300, C44400, and C44500	4 [100.0] and under	45 [310]	15 [105]	15 [105]	35 [35]
C46400, C46500	3 [80.0] and under	50 [345]	20 [140]	20 [140]	35 [35]
	over 3 to 5 [80.0 to 140.0], incl	50 [345]	18 [125]	18 [125]	35 [35]
C61300	2 [50.0] and under	75 [515]	37 [255]	36 [250]	30 [30]
	over 2 to 3 [50.0 to 80.0], incl	70 [485]	30 [205]	28 [195]	35 [35]
	over 3 to 5 [80.0140.0], incl	65 [450]	28 [195]	26 [180]	35 [35]
C61400	2 [50.0] and under	70 [485]	30 [205]	28 [195]	35 [35]
	over 2 to 5 [50.0 to 140.0], incl	65 [450]	28 [195]	26 [180]	35 [35]
C63000 and C63200	2 [50.0] and under	90 [620]	36 [250]	34 [235]	10 [10]
	over 2 to 3.5 [50.0 to 100.0], incl	85 [585]	33 [230]	31 [215]	10 [10]
	over 3.5 to 5.0 [100.0 to 140.0], incl	80 [550]	30 [205]	28 [195]	10 [10]
C70600 and C70620	2.5 [60.0] and under	40 [275]	15 [105]	15 [105]	30 [30]
	over 2.5 to 5 [60.0 to 140.0], incl	40 [275]	15 [105]	15 [105]	30 [30]
C71500 and C71520	2.5 [60.0] and under	50 [345]	20 [140]	20 [140]	30 [30]
	over 2.5 to 5 [60.0 to 140.0], incl	45 [310]	18 [125]	18 [125]	30 [30]
C72200	2.5 [60.0] and under	42 [290]	16 [110]	16 [110]	35 [35]

[A] ksi = 1000 psi.
[B] Yield strength is ~~determined as the stress producing an elongation of 0.5 % or under load, that is~~measured at 0.5 % extension under load (that is, 0.01 in. [0.254 mm] in a gage length of 2 in. [50.0 ~~mm]~~.mm]).
[C] ~~See 4.1.9.~~

9.1.2 The thickness tolerances for plates of Copper Alloy UNS Nos. C61300, C61400, C63000, C63200, C71500, C70620, C71520, and C72200 shall be 25 % greater than those prescribed in Table 2.

9.1.3 If plates are machined, the thickness tolerances shall apply to the machined portion only.

9.1.4 Closer thickness tolerances than those prescribed in Table 2 can be furnished by surface machining. This is a special product and is subject to agreement between the manufacturer and the purchaser. This special product shall apply only when specified by the purchaser in the contract or order.

9.1.5 Unless otherwise agreed to by the manufacturer and the purchaser, the thickness of plate to this specification shall be determined by measuring along the length of the plate up to a distance of 7 in. [180 mm] from the edge.

9.2 *Diameters, Lengths, or Widths*—The diameters, lengths, or widths of plates shall be not less than those specified. The diameters, lengths, or widths of plates may exceed those specified by the amounts shown in Table 4.

NOTE 2—For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the specified limiting values for any dimension may be cause for rejection.

9.3 *Flatness*—The flatness tolerances of individual plates shall not exceed those prescribed in Table 5. The tolerances shown are the total permissible variations for plates as ordered, and do not apply to the ~~7-in. [180-mm]~~ 7 in. [180 mm] marginal area at the edge of the plate. Inspection for flatness shall be made by placing the plate on a flat surfaced table with the side marked "Straight Side" up, applying a ~~72-in. [2-m]~~ 72 in. [2 m] straightedge when the size permits, or a shorter one equal to the dimensions to be inspected, and measuring the depth of arc between the straightedge and the plate.

9.4 *Plate and Sheet Lot Weight for Pressure Vessels*—When plate or sheet of Copper Alloy UNS Nos. C70600, C70620, C71500, C71520, or C72200 are ordered for pressure vessels exclusively, the maximum lot weight restriction in Table 6 shall apply in addition to the thickness tolerance requirement of Table 2. The weight of each lot of five or more plates or sheets shall not exceed the nominal weight by more than the amount prescribed in Table 6. Plate and sheet of lots of less than five shall be governed solely by the thickness tolerances of Table 2. For purposes of calculating weights, the densities used shall be as listed in Table 7.

TABLE 4 Diameter, Length, or Width Tolerances

Diameter, Length, or Width in. [mm]	Permissible Excess in Diameter, Length, or Width, in. [mm]
36 [1000] or under	3/64 [1.2]
Over 36 to 60 [1000 to 1500], incl	1/16 [1.6]
Over 60 to 96 [1500 to 2500], incl	3/32 [2.4]
Over 96 to 132 [2500 to 3500], incl	7/64 [2.8]

TABLE 5 Flatness Tolerances

Copper Alloy UNS No.	Flatness Tolerances (Depth of Arc) Not to Exceed, in. [mm], for Diameters, Lengths, or Widths Shown		
	36 in. [1000 mm] or Under	Over 36 to 60 in. [1000 to 1500 mm], incl	Over 60 to 132 in. [1500 to 3500 mm], incl[A]
C36500, C46400, and C46500	0.050 [1.3]	0.055 [1.4]	0.060 [1.5]
C44300, C44400, and C44500	0.050 [1.3]	0.065 [1.7]	0.075 [1.9]
C61300, C61400, C63000, and C63200	0.060 [1.5]	0.075 [1.9]	0.090 [2.3]
C70600, C71500, C72200, C70620, and C71520	0.060 [1.5]	0.075 [1.9]	0.090 [2.3]

[A] Tolerance applies to any ~~72 in. [1.83 m]~~ 72 in. [1.83 m] chord.

10. Workmanship, Finish, and Appearance

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

11. Sampling

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

11.1.1 *Lot Size*—10 000 ~~lbs~~lb [4550 kg] or less material of the same mill form, alloy, temper, and thickness, subject to inspection at one time.

11.1.2 *Portion Size*—Four individual sample pieces shall be selected as representative of each lot. If the lot consists of less than four pieces, samples shall be selected so as to be representative of each piece.

11.2 *Chemical Analysis*—A sample for chemical analysis shall be taken and prepared in accordance with Practice E255. Drillings, millings, and so forth, shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 11.1.2 and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

11.2.1 Instead of sampling in accordance with Practice E255, the manufacturer shall have the option of determining conformance to chemical composition by analyzing samples taken at the time castings are poured or samples taken from the semi-finished product. If the manufacturer determines the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product. The number of samples taken for determination of chemical composition shall be as follows:

11.2.1.1 When samples are taken at the time the castings are poured, at least one sample shall be taken for each group of castings poured simultaneously from the same source of molten metal.

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

11.2.2 Because of the discontinuous nature of the processing of castings into wrought products, it is not practical to keep specific casting analysis identified with a specific quantity of finished material.

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

12. Number of Tests and Retests

12.1 *Tests:*

12.1.1 *Chemical Analysis*—Chemical composition shall be determined as the per element mean of results from at least two replicate analyses of the ~~sample(s), and the results of each replication shall meet the requirements of the product specification.~~ sample(s).

12.2 *Other Tests*—For other tests, a specimen shall be taken from two of the sample pieces selected in accordance with 11.1.2. The required tests shall be made on each of the specimens so selected.

12.3 *Retests:*

12.3.1 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

12.3.2 If the percent elongation of any test specimen is less than that specified, and any part of the fracture is outside the middle two-thirds of the gage length, or in a punched or scribed mark within the reduced section, a retest shall be allowed.

12.3.3 If one of the tests made to determine any of the mechanical properties fails to meet a specified limit, this test shall be repeated on two of the remaining pieces selected in accordance with 11.1.2, and the results of both of these tests shall comply with the specified requirements.