Designation: B96/B96M – 16

Standard Specification for Copper-Silicon Alloy Plate, Sheet, Strip, and Rolled Bar for General Purposes and Pressure Vessels[1]

This standard is issued under the fixed designation B96/B96M; 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 establishes the requirements for copper-silicon alloy plate, sheet, strip, and rolled bar for drawing, forming, stamping, bending, and general engineering applications, and for pressure vessel applications. The alloys involved are copper alloys UNS Nos. C65100, C65400, and C65500.

1.2 When product is ordered for *ASME Boiler and Pressure Vessel Code* applications, consult the Code[2] for applicable alloys.

1.3 *Units*—The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, SI units are shown in brackets. The values 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.

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)

B846 Terminology for Copper and Copper Alloys

E8/E8M Test Methods for Tension Testing of Metallic Materials

E54 Test Methods for Chemical Analysis of Special Brasses and Bronzes (Withdrawn 2002)[4]

E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)[4]

E118 Test Methods for Chemical Analysis of Copper-Chromium Alloys (Withdrawn 2010)[4]

E478 Test Methods for Chemical Analysis of Copper Alloys

3. General Requirements

3.1 The following sections of either Specifications B248 or B248M constitute a part of this specification:

3.1.1 Terminology
3.1.2 Materials and Manufacture
3.1.3 Dimensions, Mass, and Permissible Variations
3.1.4 Workmanship, Finish, and Appearance
3.1.5 Sampling
3.1.6 Number of Tests and Retests
3.1.7 Test Specimens
3.1.8 Test Methods
3.1.9 Significance of Numerical Limits
3.1.10 Inspection
3.1.11 Rejection and Rehearing
3.1.12 Certification
3.1.13 Test Reports
3.1.14 Product Identification
3.1.15 Packing and Package Marking
3.1.16 Supplementary Requirements

3.2 In addition, when a section with a title identical to that referenced in 3.1 above appears in this specification, it contains additional requirements which supplement those appearing in either Specifications B248 or B248M.

4. Terminology

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

[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–96 in Section 11 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 Document Summary page on the ASTM website.

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

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

5. Ordering Information

5.1 Include the following specified choices when placing orders for product under this specification, as applicable:

5.1.1 ASTM designation and year of issue,

5.1.2 Copper [Alloy] UNS No. designation (Section 1),

5.1.3 Temper (Section 7),

5.1.4 Dimensions, Thickness, Width, and Length (Section 10),

5.1.5 How furnished: straight lengths or coils,

5.1.6 Quantity—total weight or total length or number of pieces of each size (10.7),

5.1.7 Intended application,

5.1.8 Finish (11.2), and

5.1.9 Type of edge, if required (slit, sheared, sawed, square corners, round corners, rounded edges, or full rounded edges) (10.6).

5.2 The following options are available but may not be included unless specified at the time of placing the order when required.

5.2.1 Certification,

5.2.2 Test Report,

5.2.3 Product identification for *ASME Boiler and Pressure Vessel Code* applications (Specifications B248 or B248M),

5.2.4 If product is ordered for *ASME Boiler and Pressure Vessel Code* application, (1.2, 10.1, 10.2.1, and 10.7.2),

5.2.5 Whether 0.2 % yield strength is required (Tables 1 and 2),

5.2.6 If product is purchased for agencies of the U.S. Government (see the Supplementary Requirements section of Specifications B248 or B248M for additional requirements, if specified), and

5.2.7 If specification number must be shown on package marking.

6. Chemical Composition

6.1 The material shall conform to the chemical composition requirements in Table 3 for the copper [alloy] UNS No. designation specified in the ordering information.

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

6.2.1 For alloys in which copper is listed as "remainder," copper is the difference between the sum of results of all elements determined and 100 %. When all the elements in Table 3 are determined, the sum of results shall be 99.5 % min.

7. Temper

7.1 The standard tempers for products described in this specification are in Tables 1 and 2 and Tables 4 and 5.

7.1.1 Hot rolled temper M20.

7.1.2 Hot rolled and rerolled temper M25.

7.1.3 Cold rolled tempers H01 to H14.

7.1.4 Annealed tempers O50 or O61.

8. Grain Size for Annealed Tempers

8.1 The approximate grain size values for annealed tempers given in Tables 1 and 2 and Tables 4 and 5 are for general information and shall not be used as a basis for product rejection.

9. Mechanical Property Requirements

9.1 *Tensile Strength Requirements:*

9.1.1 Product furnished under this specification shall conform to the tensile requirements prescribed in Table 1, Table 2, Table 4, or Table 5, when tested in accordance with Test Methods E8/E8M.

9.1.2 Acceptance or rejection based upon mechanical properties shall depend only on the tensile requirements of the appropriate table.

9.1.3 The tension test specimens shall be taken so the longitudinal axis of the specimens is parallel to the direction of rolling.

9.2 *Yield Strength Requirement:*

9.2.1 Product furnished under this specification shall be capable of conforming to the yield strength requirements prescribed in Tables 1 and 2 when tested in accordance with Test Methods E8/E8M. The purchaser must specify at the time of ordering which yield strength method shall be used.

9.3 *Elongation Requirement:*

9.3.1 Product furnished under this specification shall be capable of conforming to the elongation requirements prescribed in Tables 1 and 2 when tested in accordance with Test Methods E8/E8M.

9.4 *Rockwell Hardness Requirement:*

9.4.1 The approximate Rockwell hardness values given in Tables 1 and 2 and Tables 4 and 5 are for general information and assistance in testing, and shall not be used as a basis for product rejection.

10. Dimensions, Mass, and Permissible Variations

10.1 The dimensions and tolerances for product described by this specification shall be as specified in Specifications

TABLE 1 Tensile Strength Requirements and Approximate Rockwell Hardness and Grain Size Values for Pressure Vessel Applications (Inch-Pound Units)

Temper Designation		Tensile Strength, ksi	Yield Strength at 0.5 % Extension Under Load, ksi min	Yield Strength[A] at 0.2 % offset, min, ksi	Elongation, min %[B]	Approximate Rockwell F Hardness	Approximate Grain Size, mm
Code	Name						
Copper Alloy UNS No. C65500							
O61	Annealed	50–67	18	18	40	70–82	0.110 max[C]

[A] See 5.2.5.

[B] Elongation in 2 in.

[C] No minimum grain size requirement is specified, but all annealed material shall be fully recrystallized.

TABLE 2 Tensile Strength Requirements and Approximate Rockwell Hardness and Grain Size Values for Pressure Vessel Applications (SI Units)

Temper Designation		Tensile Strength, MPa	Yield Strength at 0.5 % Extension Under Load, MPa min	Yield Strength[A] at 0.2 % offset, min, MPa	Elongation, min %[B]	Approximate Rockwell F Hardness	Approximate Grain Size, mm
Code	Name						
Copper Alloy UNS No. C65500							
O61	Annealed	345–460	125	125	40	70–82	0.110 max[C]

[A] See 5.2.5.
[B] Elongation in 50 mm.
[C] No minimum grain size requirement is specified, but all annealed material shall be fully recrystallized.

TABLE 3 Chemical Requirements

Element	Composition, %		
	Copper Alloy UNS No.		
	C65100	C65400	C65500
Copper, incl silver	remainder	remainder	remainder
Silicon	0.8–2.0	2.7–3.4	2.8–3.8
Manganese	0.7 max	. . .	0.50–1.3
Tin	. . .	1.2–1.9	. . .
Chromium	. . .	0.01–0.12	. . .
Zinc, max	1.5	0.50	1.5
Iron, max	0.8	. . .	0.8
Nickel, max[A]	. . .	. . .	0.6
Lead, max	0.05	0.05	0.05

[A] Incl cobalt.

B248 or B248M with particular reference to the following tables and related paragraphs (exceptions for *ASME Pressure Vessel Code* applications are noted):

10.2 *Thickness*—Table 2.

10.2.1 *Pressure Vessel Code Applications*—The thickness of any plate or sheet shall not be more than 0.01 in. under the thickness specified.

10.3 *Width:*

10.3.1 *Slit Metal and Slit Metal with Rolled Edges*—Table 4.

10.3.2 *Square Sheared Metal*—Table 5.

10.3.3 *Sawed Metal*—Table 6.

10.4 *Length:*

10.4.1 *Length Tolerance for Straight Lengths*—Table 7.

10.4.2 *Schedule for Minimum Lengths and Maximum Weights of Ends for Specific Lengths with Ends, and Stock Lengths with Ends*—Table 8.

10.4.3 *Length Tolerances for Square Sheared Metal*—Table 9.

10.4.4 *Length Tolerances for Sawed Metal*—Table 10.

10.5 *Straightness:*

10.5.1 *Slit Metal or Slit Metal Either Straightened or Edge Rolled*—Table 11.

10.5.2 *Square Sheared Metal*—Table 12.

10.5.3 *Sawed Metal*—Table 13.

10.6 *Edges Contours:*

10.6.1 *Square Corners*—Table 14.

10.6.2 *Rounded Corners*—Table 15.

10.6.3 *Rounded Edges*—Table 16.

10.6.4 *Full-Rounded Edges*—Table 17.

10.7 *Weight:*

10.7.1 *Lot Weight Tolerances for Hot-Rolled Sheet and Plate*—Table 18.

10.7.2 *ASME Pressure Vessel Code Applications*—Table 6 of this specification.

11. Workmanship, Finish, and Appearance

11.1 For workmanship and appearance requirements, refer to Specifications B248 or B248M.

11.2 *Finish*—The material is supplied regularly in the following finishes:

11.2.1 *Black*—After hot rolling retains all of the oxides.

11.2.2 *Plain Pickled*—Sulfuric acid pickle only, brick red oxide; has cuprous and silicon oxides still adherent.

11.2.3 *Specially Cleaned*—Commercially free of all oxides; has the golden color of the alloy.

11.2.4 *Sand Blasted*—Commercially free of all oxides; has a dull gray color.

12. Sampling

12.1 Refer to sampling section in Specifications B248 or B248M.

13. Test Methods

13.1 *Chemical Analysis:*

13.1.1 In cases of disagreement, test methods for chemical analysis shall be subject to agreement between the manufacturer or supplier and the purchaser. The following table is a list of published test methods, some of which may no longer be viable, which along with others not listed, may be used subject to agreement.

Element	ASTM Test Method
Copper	E478
Silicon	E54; Perchloric acid dehydration
Manganese	E62
Tin	E478; Titrimetric
Chromium	E118
Zinc	E478; Atomic absorption
Iron	E478
Nickel	E478; Photometric
Lead	E478; Atomic absorption

13.1.2 Test method(s) to be followed for the determination of element(s) resulting from contractual or purchase order agreement shall be as agreed upon between the manufacturer or supplier and purchaser.

13.2 *Other Tests:*

13.2.1 *Mechanical Properties (Tensile Strength, Yield Strength, Elongation, Rockwell Hardness, and Grain Size)*—Refer to the appropriate test method in Specifications B248 or B248M.

TABLE 4 Tensile Strength Requirements and Approximate Rockwell Hardness and Grain Size Values (Inch-Pound Units)

Temper Designation		Tensile Strength,	Approximate Rockwell Hardness		Approximate Grain
Code	Name	ksi	F Scale	B Scale	Size, mm
		Copper Alloy UNS No. C65100			
O61	Annealed	38–45	45–55	. . .	0.050–0.120
O50	Light anneal	40–50	50–75	. . .	0.060 max[A]
H01	Quarter-hard	42–52	. . .	48–63	. . .
H02	Half-hard	47–57	. . .	64–73	. . .
H04	Hard	60–70	. . .	74–82	. . .
H06	Extra-hard	67–76	. . .	78–85	. . .
H08	Spring	71–79	. . .	81–86	. . .
		Copper Alloy UNS Nos. C65500			
O61	Annealed	52–58	70–82	. . .	0.110 max[A]
O50	Light anneal	55–64	76–93	. . .	0.055 max[B]
H01	Quarter-hard	60–74	. . .	65–80	. . .
H02	Half-hard[B]	72–86	. . .	79–91	. . .
H04	Hard[B]	85–99	. . .	88–96	. . .
H06	Extra-hard[B]	95–109	. . .	93–98	. . .
H08	Spring[B]	102–116	. . .	94–99	. . .
M20	As hot-rolled	55–72	72 min	. . .	. . .
M25	As hot-rolled and rerolled	58–72	. . .	60-80	. . .
	Copper Alloy UNS No. C65400		Superficial 30T	B Scale	
O61	Annealed	65–80	. . .	. . .	0.040[B] max
H01	Quarter hard[B]	75–90	64–77	72–91	. . .
H02	Half hard[B]	86–101	75–79	89–95	. . .
H03	Three-quarter hard[B]	97–112	77–81	94–97	. . .
H04	Hard[B]	108–120	80–81	96–98	. . .
H06	Extra hard[B]	116–126	81–82	97–100	. . .
H08	Spring[B]	124–133	81–82	99–101	. . .
H10	Extra spring[B]	131–140	81 min	100–102	. . .
H14	Super spring[B]	137 min	81 min	101 min	. . .

[A] No minimum grain size requirement is specified, but all annealed material shall be fully recrystallized.
[B] Commercially supplied only as strip. The manufacturer should be consulted where these tempers are desired in sheet or plate.

TABLE 5 Tensile Strength Requirements and Approximate Rockwell Hardness and Grain Size Values (SI Units)

Temper Designation		Tensile Strength,	Approximate Rockwell Hardness		Approximate Grain
Code	Name	MPa	F Scale	B Scale	Size, mm
		Copper Alloy UNS No. C65100			
O61	Annealed	260–310	45–55	. . .	0.050–0.120
O50	Light anneal	275–345	50–75	. . .	0.060 max[A]
H01	Quarter-hard	290–360	. . .	48–63	. . .
H02	Half-hard	325–395	. . .	64–73	. . .
H04	Hard	415–485	. . .	74–82	. . .
H06	Extra-hard	460–525	. . .	78–85	. . .
H08	Spring	490–545	. . .	81–86	. . .
		Copper Alloy UNS Nos. C65500			
O61	Annealed	360–400	70–82	. . .	0.110 max[A]
O50	Light anneal	380–440	76–93	. . .	0.055 max[B]
H01	Quarter-hard	415–510	. . .	65–80	. . .
H02	Half-hard[B]	495–595	. . .	79–91	. . .
H04	Hard[B]	585–685	. . .	88–96	. . .
H06	Extra-hard[B]	655–750	. . .	93–98	. . .
H08	Spring[B]	705–800	. . .	94–99	. . .
M20	As hot-rolled	380–495	72 min	. . .	. . .
M25	As hot-rolled and rerolled	400–495	. . .	60-80	. . .
	Copper Alloy UNS No. C65400		Superficial 30T	B Scale	
O61	Annealed	450–550	. . .	. . .	0.040[B] max
H01	Quarter hard[B]	515–620	64–77	72–91	. . .
H02	Half hard[B]	595–695	75–79	89–95	. . .
H03	Three-quarter hard[B]	670–770	77–81	94–97	. . .
H04	Hard[B]	745–825	80–81	96–98	. . .
H06	Extra hard[B]	800–870	81–82	97–100	. . .
H08	Spring[B]	855–915	81–82	99–101	. . .
H10	Extra spring[B]	905–965	81 min	100–102	. . .
H14	Super spring[B]	945 min	81 min	101 min	. . .

[A] No minimum grain size requirement is specified, but all annealed material shall be fully recrystallized.
[B] Commercially supplied only as strip. The manufacturer should be consulted where these tempers are desired in sheet or plate.

TABLE 6 Lot Weight Tolerances in Percentage of Theoretical Weight for Pressure Vessel Applications—All Plus

Thickness, in. [mm]	Permissible Excess in Average Weight of Lots, Expressed in Percentage of Normal Weight					
	48 in. [1200 mm] and Under in Width	Over 48 to 60 in. [1200 to 1500 mm] in Width	Over 60 to 72 in. [1500 to 1800 mm] in Width	Over 72 to 96 in. [1800 to 2500 mm] in Width	Over 96 to 120 in. [2500 to 3000 mm] in Width	Over 120 to 132 in. [3000 to 3500 mm] incl in Width
⅛ to 3⁄16, incl [3.0 to 5.0]	6.5	8	9	11	. . .	. . .
Over 3⁄16 to ¼, incl [6.0 to 8.0]	6.5	8	9	11	12	. . .
Over ¼ to 5⁄16, incl [8.0 to 10]	6.5	7.75	8.75	11	12	13
Over 5⁄16 to ⅜, incl [9.0 to 10]	6.25	7.5	8.5	11	12	13
Over ⅜ to 7⁄16, incl [10 to 12]	6	7.25	8.25	11	12	13
Over 7⁄16 to ½, incl [12 to 14]	6	7	8	10	11	12
Over ½ to ⅝, incl [14 to 16]	5.75	6.5	7.5	9	10	11
Over ⅝ to ¾, incl [16 to 20]	5.5	6	7	8	9	10
Over ¾ to 1, incl [20 to 25]	5	5	6.25	7	8	9
Over 1 to 2, incl [25 to 50]	3.5	4	5	6	7	8

14. Keywords

14.1 copper-silicon alloy plate; copper-silicon alloy pressure vessels; copper-silicon alloy rolled bar; copper-silicon alloy sheet; copper-silicon alloy strip; UNS No. C65100; UNS No. C65400; UNS No. C65500

SUMMARY OF CHANGES

Committee B05 has identified the principal changes to this specification that have been incorporated since the 2011 issue as follows:

(1) Revised to comply with the B950-13, Standard Guide for Editorial Procedures and Form of Product Specifications for Copper and Copper Alloys.
(2) Corrected M20 and M25 Tensile Strength Max for Alloy C65500 from 500 to 495 MPa.
(3) Corrected errors in Table 5 Tensile Strength Requirements for Alloy C65400. H01 Min changed to 515 MPa from 520 MPa, H02 Min changed to 595 MPa from 590 MPa, H02 Max changed to 695 MPa from 700 MPa, H04 Max changed to 825 MPa from 830 MPa, and H08 Max changed to 915 MPa from 920 MPa.