



Designation: **B249/B249M—16 B249/B249M – 17**

Standard Specification for General Requirements for Wrought Copper and Copper- Alloy Rod, Bar, Shapes and Forgings¹

This standard is issued under the fixed designation B249/B249M; 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 specification² establishes the general requirements common to wrought copper and copper alloy rod, bar, shapes, and forgings which shall apply to Specifications **B16/B16M**, **B21/B21M**, **B98/B98M**, **B124/B124M**, **B138/B138M**, **B139/B139M**, **B140/B140M**, **B150/B150M**, **B151/B151M**, **B187/B187M**, **B196/B196M**, **B283/B283M**, **B301/B301M**, **B371/B371M**, **B411/B411M**, **B441**, **B453/B453M**, **B455**, **B570**, **B870**, **B927/B927M**, **B929**, **B967/B967M**, and **B974/B974M** to the extent referenced therein.

1.2 The chemical composition, physical and mechanical properties, and all other requirements not included in this specification are prescribed in the product specification.

1.3 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. 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.

1.3.1 Within the text the SI values are given in brackets.

1.4 *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.*

1.5 *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
- B16/B16M** Specification for Free-Cutting Brass Rod, Bar and Shapes for Use in Screw Machines
 - B21/B21M** Specification for Naval Brass Rod, Bar, and Shapes
 - B98/B98M** Specification for Copper-Silicon Alloy Rod, Bar and Shapes
 - B124/B124M** Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes
 - B138/B138M** Specification for Manganese Bronze Rod, Bar, and Shapes
 - B139/B139M** Specification for Phosphor Bronze Rod, Bar, and Shapes
 - B140/B140M** Specification for Copper-Zinc-Lead (Red Brass or Hardware Bronze) Rod, Bar, and Shapes
 - B150/B150M** Specification for Aluminum Bronze Rod, Bar, and Shapes
 - B151/B151M** Specification for Copper-Nickel-Zinc Alloy (Nickel Silver) and Copper-Nickel Rod and Bar
 - B154** Test Method for Mercurous Nitrate Test for Copper Alloys
 - B187/B187M** Specification for Copper, Bus Bar, Rod, and Shapes and General Purpose Rod, Bar, and Shapes
 - B193** Test Method for Resistivity of Electrical Conductor Materials
 - B194** Specification for Copper-Beryllium Alloy Plate, Sheet, Strip, and Rolled Bar

¹ This specification is under the jurisdiction of ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.02 on Rod, Bar, Wire, Shapes and Forgings.

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² For ASME Boiler and Pressure Vessel Code applications see related Specifications SB-249 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 Document Summary page on the ASTM website.

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



B196/B196M Specification for Copper-Beryllium Alloy Rod and Bar
B283/B283M Specification for Copper and Copper-Alloy Die Forgings (Hot-Pressed)
B301/B301M Specification for Free-Cutting Copper Rod, Bar, Wire, and Shapes
B371/B371M Specification for Copper-Zinc-Silicon Alloy Rod
B411/B411M Specification for Copper-Nickel-Silicon Alloy Rod and Bar
B441 Specification for Copper-Cobalt-Beryllium, Copper-Nickel-Beryllium, and Copper-Nickel-Lead-Beryllium Rod and Bar (UNS Nos. C17500, C17510, and C17465)
B453/B453M Specification for Copper-Zinc-Lead Alloy (Leaded-Brass) Rod, Bar, and Shapes
B455 Specification for Copper-Zinc-Lead Alloy (Leaded-Brass) Extruded Shapes
B570 Specification for Copper-Beryllium Alloy (UNS Nos. C17000 and C17200) Forgings and Extrusions
B577 Test Methods for Detection of Cuprous Oxide (Hydrogen Embrittlement Susceptibility) in Copper
B846 Terminology for Copper and Copper Alloys
B858 Test Method for Ammonia Vapor Test for Determining Susceptibility to Stress Corrosion Cracking in Copper Alloys
B870 Specification for Copper-Beryllium Alloy Forgings and Extrusions Alloys (UNS Nos. C17500 and C17510)
B900 Practice for Packaging of Copper and Copper Alloy Mill Products for U.S. Government Agencies
B927/B927M Specification for Brass Rod, Bar, and Shapes
B929 Specification for Copper-Nickel-Tin Spinodal Alloy Rod and Bar
B967/B967M Specification for Copper-Zinc-Tin-Bismuth Alloy Rod, Bar and Wire
B974/B974M Specification for Free-Cutting Bismuth Brass Rod, Bar and Wire
D4855 Practice for Comparing Test Methods (Withdrawn 2008)⁴
E3 Guide for Preparation of Metallographic Specimens
E8/E8M Test Methods for Tension Testing of Metallic Materials
E18 Test Methods for Rockwell Hardness of Metallic Materials
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E53 Test Method for Determination of Copper in Unalloyed Copper by Gravimetry
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
E75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys (Withdrawn 2010)⁴
E76 Test Methods for Chemical Analysis of Nickel-Copper Alloys (Withdrawn 2003)⁴
E112 Test Methods for Determining Average Grain Size
E118 Test Methods for Chemical Analysis of Copper-Chromium Alloys (Withdrawn 2010)⁴
E121 Test Methods for Chemical Analysis of Copper-Tellurium Alloys (Withdrawn 2010)⁴
E255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition
E290 Test Methods for Bend Testing of Material for Ductility
E478 Test Methods for Chemical Analysis of Copper Alloys
E581 Test Methods for Chemical Analysis of Manganese-Copper Alloys

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *lengths, mill, n*—straight lengths, including ends, that can be conveniently manufactured in the mill. Full length pieces are usually 10 or 12 ft [3000 or 3600 mm].

3.2.2 *lengths, stock, n*—straight lengths that are mill cut and stored in advance of orders. They are usually 10 or 12 ft [3000 or 3600 mm] and subject to established length tolerances.

4. Materials and Manufacture

4.1 *Materials:*

4.1.1 The material of manufacture shall be a form of the Copper or Copper Alloy UNS No. designation specified in the ordering information of such purity and soundness as to be suitable for processing into the products described in the product specification.

4.1.2 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 specific casting analysis with a specific quantity of finished product.

4.2 *Manufacture*—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.

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

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

4.2.2 *Edges*—The edge shall be drawn, extruded, or rolled; refer to Edge Contours in Section 6.

5. Chemical Composition

5.1 The material shall conform to the chemical composition requirements prescribed in the product specification.

5.1.1 Results of analysis on a product (check) sample shall conform to the composition requirements within the permitted analytical variance given in the product specification.

5.2 The composition limits established for the Copper or Copper Alloy UNS No. designation specified in the product specification do not preclude the presence of other elements. By agreement between the manufacturer or supplier and the purchaser. Limits may be established and analysis required for unnamed elements.

5.3 When material composition has been determined during the course of manufacture, analysis of the finished product by the manufacturer is not required.

6. Dimensions, Mass and Permissible Variations

6.1 *General*—For the purpose of determining conformance with the dimensional requirements, any measured value outside the specified limiting values for any dimension may be cause for rejection.

6.1.1 The dimensions and tolerances for products referenced to this specification, shall be as noted in the following paragraphs and tables, where the product specification is noted in the table heading.

NOTE 2—Blank spaces in the tolerance tables indicate either that the material generally is not available or that no tolerances are established.

6.2 *Diameter or Distance Between Parallel Surfaces*—The diameter of round sections or the distance between parallel surfaces in the case of other sections, except shapes, shall not vary from that specified by more than the amounts specified in **Tables 1-12**, incl, for the product, specification indicated:

Table 1 and **Table 2**—List the tolerances for diameter or distance between parallel surfaces of cold-drawn rod in round, hexagonal and octagonal cross sections. Applicable product specifications and alloys are shown in the table titles.

Table 3—Lists the diameter tolerances for piston finish rod applicable to product specifications shown in the table title.

Table 4 and **Table 5**—List the tolerances for diameter or distance between parallel surfaces of as-extruded rod and bar applicable to the specifications and alloys shown in the table titles. These tolerances are applicable to round, hexagonal, and octagonal rod as well as square and rectangular bar.

Table 6—Lists the diameter tolerances for hot-rolled round rod applicable to the product specification shown in the table title.

Table 7, **Table 8** and **Table 9**—List the thickness tolerances for rectangular and square bar applicable to the product specifications and alloys shown in the table titles.

Table 10 and **Table 11**—List the width tolerances for rectangular bar applicable to the product specifications and alloys shown in the table titles.

Table 12—Lists the diameter or distance between parallel surfaces tolerances for hot-forged rod and bar applicable to the product specification shown in the title.

6.3 *Length*—Rod, bar, and shapes shall be furnished in stock lengths with ends, unless the order specifies stock lengths, specific lengths, or specific lengths with ends as specified in **Table 13**, **Table 14**, and **Table 15** for the product specification indicated:

TABLE 1 Tolerances for Diameter or Distance Between Parallel Surfaces of Cold-Drawn Rod

(Applicable to Specifications **B16/B16M**, **B21/B21M**, **B98/B98M** (Copper Alloy UNS No. C65100), **B124/B124M** (Copper Alloy UNS Nos. C11000, C14500, C14700, C46400, C46750, C48200, C48500, C49250, C49255, C49260, C49265, C49300, C49340, C49345, C49350, and C49360), **B140/B140M**, **B301/B301M**, **B453/B453M**, **B927/B927M**, **B967/B967M**, and **B974/B974M**)

Diameter or Distance Between Parallel Surfaces, in. [mm]	Tolerances, Plus and Minus, ^A in. [mm]	
	Round	Hexagonal, Octagonal
Up to 0.150 [3.8], incl	0.0013 [0.035]	0.0025 [0.06]
Over 0.150 to 0.500 [3.8 to 12], incl	0.0015 [0.04]	0.003 [0.08]
Over 0.500 to 1.00 [12 to 25], incl	0.002 [0.05]	0.004 [0.10]
Over 1.00 to 2.00 [25 to 50], incl	0.0025 [0.06]	0.005 [0.13]
Over 2.00 [50]	0.15 ^B [0.15] ^B	0.30 ^B [0.30] ^B

^A When tolerances are specified as all plus or all minus, double the values given.

^B Percent of specified diameter or distance between parallel surfaces expressed to the nearest 0.001 in. [0.01 mm].



TABLE 2 Tolerances for Diameter or Distance Between Parallel Surfaces of Cold-Drawn Rod

(Applicable to Specifications B98/B98M (Copper Alloy UNS No. C65500 and C66100), B124/B124M (Copper Alloy UNS Nos. C27450, C27453, C28500, C36500, C37000, C37700, C61900, C62300, C63000, C63200, C64200, C64210, C65500, C67500, C67600, C69240, C69300, C70620, C71520, and C77400), B138/B138M, B139/B139M, B150/B150M, B151/B151M, B196/B196M, B371/B371M, B411/B411M, and B441)

Diameter or Distance Between Parallel Surfaces, in. [mm]	Tolerances, Plus and Minus, ^A in. [mm]	
	Round	Hexagonal, Octagonal
Up to 0.150 [3.8], incl	0.002 [0.050]	0.002 [0.050]
Over 0.150 to 0.500 [3.8 to 12], incl	0.002 [0.050]	0.004 [0.10]
Over 0.500 to 1.00 [12 to 25], incl	0.003 [0.08]	0.005 [0.13]
Over 1.00 to 2.00 [25 to 50], incl	0.004 [0.10]	0.006 [0.15]
Over 2.00 [50]	0.20 ^B [0.20] ^B	0.40 ^B [0.40] ^B

^A When tolerances are specified as all plus or all minus, double the values given.
^B Percent of specified diameter or distance between parallel surfaces expressed to the nearest 0.001 in. [0.01 mm].

TABLE 3 Diameter Tolerances for Piston-Finish Rod
 (Applicable to Specifications B21/B21M, B138/B138M, B139/B139M, and B150/B150M)

Diameter, in. [mm]	Tolerances, Plus and Minus, ^A in. [mm]
Over 0.500 to 1.00 [12 to 25], incl	0.0013 [0.35]
Over 1.00 to 2.00 [25 to 50], incl	0.0015 [0.04]
Over 2.00 [50]	0.10 ^B [0.10] ^B

^A When tolerances are specified as all plus or all minus, double the values given.
^B Percent of specified diameter expressed to the nearest 0.0005 in. [0.01 mm].

TABLE 4 Tolerances for Diameter or Distance Between Parallel Surfaces of As-Extruded Rod and Bar

(Applicable to Specifications B21/B21M, B124/B124M (Copper Alloy UNS Nos. C27450, C27453, C28500, C36500, C37000, C37700, C46400, C46750, C48200, C48500, C49250, C49255, C49260, C49265, C49300, C49340, C49345, C49350, C49355, C49360, C61900, C62300, C63000, C63200, C64200, C64210, C67500, C67600, C69240, C69300, C70620, and C71520), B138/B138M (Copper Alloy UNS Nos. C67500 and C67600), B150/B150M, and B967/B967M)

Diameter or Distance Between Parallel Surfaces, in. [mm]	Tolerances, Plus and Minus, ^A in. [mm]
	Rod (Round, Hexagonal, and Octagonal) Bar (Rectangular and Square)
Up to 1.00 [25], incl	0.010 [0.25]
Over 1.00 to 2.00 [25 to 50], incl	0.015 [0.38]
Over 2.00 to 3.00 [50 to 75], incl	0.025 [0.65]
Over 3.00 to 3.50 [75 to 90], incl	0.035 [0.90]
Over 3.50 to 4.00 [90 to 100], incl	0.060 [1.5]

^A When tolerances are specified as all plus or all minus, double the values given.

Table 13—Length tolerances for full-length pieces applicable to product specifications shown in the table title.

Table 14 and Table 15—Lists the schedule of lengths (specific and stock) with ends applicable to product specifications and alloys shown in the table titles.

6.4 Straightness:

6.4.1 Unless otherwise specified, drawn rod, bar, and shapes, other than shafting rod, piston-finish rod shall be furnished in straight lengths. The deviation from straightness shall not exceed the limitations specified in Table 16 for either general or automatic screw machine use for the product specifications and alloys shown in the table titles. To determine compliance with this tolerance, the lengths shall, in case of disagreement, be checked by the following method:

**TABLE 5 Tolerances for Diameter or Distance Between Parallel Surfaces of As-Extruded Rod and Bar**

(Applicable to Specifications B98/B98M, B124/B124M (Copper UNS Nos. C11000, C14500, C14700 and Copper Alloy UNS Nos. C65500, C77400, C87700, and C87710), B138/B138M (Copper UNS No. C67000), B196/B196M, B441 and B929)

Diameter or Distance Between Parallel Surfaces, in. [mm]	Tolerances, Plus and Minus, ^A in. [mm]
	Rod (Round, Hexagonal, and Octagonal) Bar (Rectangular and Square)
Up to 1.00 [25], incl	0.020 [0.50]
Over 1.00 to 2.00 [25 to 50], incl	0.030 [0.75]
Over 2.00 to 3.00 [50 to 75], incl	0.050 [1.3]
Over 3.00 to 3.50 [75 to 90], incl	0.070 [1.8]
Over 3.50 to 4.00 [90 to 100], incl	0.120 [3.0]

^A When tolerances are specified as all plus or all minus, double the values given.

TABLE 6 Diameter Tolerances for Hot-Rolled Round Rod
(Applicable to Specifications B98/B98M, B124/B124M, B138/B138M, B150/B150M, B196/B196M, and B441)

Diameter, in. [mm]	Tolerances, Plus and Minus, ^A in. [mm]
0.250 [6.35] only	+0.020 [+0.50] −0.010 [−0.25]
Over 0.250 to 0.750 [6.35 to 20], incl	0.015 [0.38]
Over 0.750 to 1.25 [20 to 30], incl	0.020 [0.50]
Over 1.25 to 1.50 [30 to 38], incl	0.030 [0.75]
Over 1.50 to 3.00 [38 to 75], incl	1/16 [1.6]
Over 3.00 [75]	1/8 [3.2]

^A When tolerances are specified as all plus or all minus, double the values given.

6.4.1.1 Place the lengths on a level table so that the arc or departure from straightness is horizontal. Measure the depth of arc to the nearest 1/32 in. [1.0 mm], using a steel scale and a straightedge. Local departure from straightness should be measured with a 1-ft [300-mm] straightedge and a feeler gage.

6.4.2 Shafting rod, when so specified, shall comply with the tolerances of Table 17 for the product specifications shown in the table title. To determine compliance with this paragraph, shafting shall, in case of disagreement, be checked by the following method:

6.4.2.1 Place the shaft upon two freely rotating supports, one fourth of the shaft length extending beyond each support. Measure the departure from straightness at each end and at the center by means of a dial gage mounted on a suitable movable block and set successively at the three points to be measured while rotating the shaft slowly and carefully to avoid vibration. The total range of the dial reading at a given point, divided by two, gives the departure from straightness at that point.

6.5 Edge Contours:

6.5.1 *Finish*—All rectangular and square bar shall have finished edges.

6.5.2 *Angles*—All regular polygonal sections shall have substantially exact angles. For hexagonal and octagonal rods cold-drawn to size, corner radii shall not exceed 1/16 in. [1.5 mm] for sizes up to 2 in. [50 mm], incl., and 3/32 in. [2.5 mm] for sizes over 2 in. [50 mm].

6.5.2.1 When specified, hexagons and octagons shall be furnished with corners rounded to a radius of 11 % of the distance between parallel faces. The distance from corner to corner (see Note 3) shall be the basis for acceptance or rejection. the appropriate tolerances are listed in Table 18.

NOTE 3—The distance from corner to corner is determined by calculating the distance across parallel faces times 1.121 for hexagons and 1.064 for octagons.

6.5.3 *Rectangular and Square Bar*—Unless otherwise specified, square corners shall be furnished on rectangular and square bar. When so ordered, the edge contours described in 6.5.4 – 6.5.7 inclusive shall be furnished.

6.5.4 *Square Corners*—Unless otherwise specified, bar shall be finished with commercially square corners with a maximum permissible radius of 1/32 in. [1.0 mm] for bars over 3/16 to 1 in. [5 to 25 mm], inclusive, in thickness, and 1/16 in. [1.5 mm] for bars over 1 in. [25 mm] in thickness.

6.5.5 *Rounded Corners*—When specified, bar shall be finished with corners rounded as shown in Fig. 1 to a quarter circle with a radius of 1/16 in. [1.5 mm] for bars over 3/16 to 1 in. [25 mm], inclusive, in thickness, and 1/8 in. [5 mm] for bars over 1 in. [25 mm] in thickness. The tolerance on the radius shall be ±25 %.



TABLE 7 Thickness Tolerances for Rectangular and Square Bar

(Applicable to Specifications B124/B124M, (Copper Alloy UNS Nos. C11000, C14500, and C14700), B301/B301M, and B974/B974M)

Table with 7 columns: Thickness, in. [mm], 1/2 [12] and Under, Over 1/2 to 1 1/4 [12 to 30] Incl, Over 1 1/4 to 2 [30 to 50] Incl, Over 2 to 4 [50 to 100] Incl, Over 4 to 8 [100 to 200] Incl, Over 8 to 12 [200 to 300] Incl. Rows include thickness ranges like 'Over 0.188 to 0.500 [4.8 to 12], incl'.

A When tolerances are specified as all plus or all minus, double the values given.

B Percent of specified thickness expressed to the nearest 0.001 in. [0.01 mm].

TABLE 8 Thickness Tolerances for Rectangular and Square Bar

(Applicable to Specifications B16/B16M, B21/B21M, B98/B98M, (Copper Alloy UNS No. 65100), B124/B124M (Copper Alloy UNS Nos. C46400, C46750, C48200, and C48500), B140/B140M, B453/B453M, B927/B927M, and B967/B967M)

Table with 7 columns: Thickness, in. [mm], 1/2 and Under, Over 1/2 to 1 1/4 Incl, Over 1 1/4 to 2 Incl, Over 2 to 4 Incl, Over 4 to 8 Incl, Over 8 to 12 Incl. Rows include thickness ranges like 'Over 0.188 to 0.500 [4.8 to 12], incl'.

A When tolerances are specified as all plus or all minus, double the values given.

B Percent of specified thickness expressed to the nearest 0.001 in. [0.01 mm].

TABLE 9 Thickness Tolerances for Rectangular and Square Bar

(Applicable to Specifications B98/B98M (Copper Alloy UNS Nos. C65500 and C66100), B124/B124M (Copper Alloy UNS Nos. C27450, C27453, C28500, C36500, C37000, C37700, C61900, C62300, C63000, C63200, C64200, C64210, C65500, C67500, C67600, C69240, C69300, C70620, C75120, C77400, C87700, and C87710), B138/B138M, B139/B139M, B150/B150M, B151/B151M, B196/B196M, B411/B411M, B441, and B929)

Table with 7 columns: Thickness, in. [mm], 1/2 [12] and Under, Over 1/2 to 1 1/4 [12 to 30] Incl, Over 1 1/4 to 2 [30 to 50] Incl, Over 2 to 4 [50 to 100] Incl, Over 4 to 8 [100 to 200] Incl, Over 8 to 12 [200 to 300] Incl. Rows include thickness ranges like 'Over 0.188 to 0.500 [4.8 to 12], incl'.

A When tolerances are specified as all plus or all minus, double the values given.

B Percent of specified thickness expressed to the nearest 0.001 in. [0.1 mm].

TABLE 10 Width Tolerances for Rectangular Bar

(Applicable to Specifications B16/B16M, B21/B21M, B98/B98M (Copper Alloy UNS No. C65100), B124/B124M (Copper Alloy UNS Nos. C11000, C14500, C14700, C46400, C46750, C48200, and C48500), B140/B140M, B301/B301M, B453/B453M, B927/B927M, B967/B967M and B974/B974M)

Table with 2 columns: Width, in. [mm], Tolerances, Plus and Minus, A in. [mm]. Rows include width ranges like 'Over 0.188 to 0.500 [4.8 to 12], incl'.

A When tolerances are specified as all plus or all minus, double the values given.

B Percent of specified width expressed to the nearest 0.001 in. [0.01 mm].

6.5.6 Rounded Edge—When specified bar shall be finished with edges rounded as shown in Fig. 2, the radius of curvature being 1 1/4 times the thickness of the bar for bars over 3/16 in. [5 mm]–[5 mm] in thickness. The tolerance on the radius shall be one fourth the thickness of the bar.

6.5.7 Full Rounded Edge—When specified, bar shall be finished with substantially uniform round edges, the radius of curvature being approximately one half the thickness of the product, as shown in Fig. 3, but in no case to exceed one half the thickness of the product by more than 25 %.