



# Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes<sup>1</sup>

This standard is issued under the fixed designation A 500; 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 specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.*

## 1. Scope

1.1 This specification covers cold-formed welded and seamless carbon steel round, square, rectangular, or special shape structural tubing for welded, riveted, or bolted construction of bridges and buildings, and for general structural purposes.

1.2 This tubing is produced in both welded and seamless sizes with a maximum periphery of 64 in. (1626 mm) and a maximum wall of 0.625 in. (15.88 mm). Grade D requires heat treatment.

NOTE 1—Products manufactured to this specification may not be suitable for those applications such as dynamically loaded elements in welded structures, etc., where low-temperature notch-toughness properties may be important.

1.3 The values stated in inch-pound units are to be regarded as the standard.

## 2. Referenced Documents

### 2.1 ASTM Standards:

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>2</sup>

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment<sup>3</sup>

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products<sup>2</sup>

### 2.2 Military Standards:

MIL-STD-129 Marking for Shipment and Storage<sup>4</sup>

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage<sup>4</sup>

### 2.3 Federal Standards:

Fed. Std. No. 123 Marking for Shipment<sup>4</sup>

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products<sup>4</sup>

## 3. Ordering Information

3.1 Orders for material under this specification should include the following, as required, to describe the desired material adequately.

- 3.1.1 Quantity (feet or number of lengths),
- 3.1.2 Name of material (cold-formed tubing),
- 3.1.3 Method of manufacture (seamless or welded),
- 3.1.4 Grade (Table 1 and 2),
- 3.1.5 Size (outside diameter and nominal wall thickness for round tubing and the outside dimensions and nominal wall thickness for square and rectangular tubing),
- 3.1.6 Length (specific or random, see 10.3),
- 3.1.7 End condition (see 15.3),
- 3.1.8 Burr removal (see 15.3),
- 3.1.9 Certification (see 15.4),
- 3.1.10 ASTM specification number,
- 3.1.11 End use, and
- 3.1.12 Special requirements.

## 4. Process

4.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

4.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

## 5. Manufacture

5.1 The tubing shall be made by a seamless or welding process.

5.2 Welded tubing shall be made from flat-rolled steel by the electric-resistance welding process. The longitudinal butt joint of welded tubing shall be welded across its thickness in such a manner that the structural design strength of the tubing section is assured.

5.2.1 Structural tubing welded by electric-resistance methods is normally furnished without removal of inside flash.

5.3 The tubing may be stress relieved or annealed as is considered necessary by the manufacturer to conform to the requirements of this specification, except as required by 5.4.

5.4 Grade D tubing shall be heat treated at a minimum temperature of 1100° F for 1 h/in. of thickness, ½ h minimum.

## 6. Heat Analysis

6.1 An analysis of each heat of open-hearth, basic-oxygen, or electric-furnace steel shall be made by the manufacturer. This analysis shall be made from a test ingot taken during the

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<sup>2</sup> Annual Book of ASTM Standards, Vol 01.03.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.05.

<sup>4</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

**TABLE 1 Chemical Requirements**

Element	Composition, %			
	Grades A, B and D		Grade C	
	Heat Analysis	Product Analysis	Heat Analysis	Product Analysis
Carbon, max	0.26	0.30	0.23	0.27
Manganese, max	...	...	1.35	1.40
Phosphorus, max	0.035	0.045	0.035	0.045
Sulfur, max	0.035	0.045	0.035	0.045
Copper, when copper steel is specified, min	0.20	0.18	0.20	0.18

pouring of the heat. The chemical composition thus determined shall conform to the requirements specified in Table 1 for heat analysis.

**7. Product Analysis**

7.1 An analysis may be made by the purchaser from finished tubing manufactured in accordance with this specification, or an analysis may be made from flat-rolled stock from which the welded tubing is manufactured. When product analyses are made, two sample lengths from a lot of each 500 lengths or fraction thereof shall be selected. Methods and practices relating to chemical analysis shall be in accordance with Test Methods, Practices and Terminology A 751. The chemical composition thus determined shall conform to the requirements specified in Table 1 for product analysis.

7.2 In the event the chemical composition of one of the sample lengths does not conform to the requirements shown in Table 1 for product analysis, an analysis of two additional lengths selected from the same lot shall be made, each of which shall conform to the requirements shown in Table 1 for product analysis, or the lot is subject to rejection.

**8. Tensile Requirements**

8.1 The material, as represented by the test specimen, shall conform to the requirements as to tensile properties prescribed in Table 2.

**9. Flattening Test**

9.1 The flattening test shall be made on round structural tubing. A flattening test is not required for shaped structural tubing.

9.2 For welded round structural tubing, a specimen at least 4 in. (102 mm) in length shall be flattened cold between parallel plates in three steps, with the weld located at 90° from the line of direction of force. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than two thirds of the original outside diameter of the tubing. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside or outside surfaces, except as provided for in 9.5, shall occur until the distance between the plates is less than one half of the original outside diameter of the tubing but is not less than five times the wall thickness of the tubing. During the third step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the tubing meet. Evidence of laminated

**TABLE 2 Tensile Requirements**

	Round Structural Tubing			
	Grade A	Grade B	Grade C	Grade D
Tensile strength, min, psi (MPa)	45 000 (310)	58 000 (400)	62 000 (427)	58 000 (400)
Yield strength, min, psi (MPa)	33 000 (228)	42 000 (290)	46 000 (317)	36 000 (250)
Elongation in 2 in. (50.8 mm), min, % <sup>A</sup>	25 <sup>B</sup>	23 <sup>C</sup>	21 <sup>D</sup>	23 <sup>C</sup>
	Shaped Structural Tubing			
	Grade A	Grade B	Grade C	Grade D
Tensile strength, min, psi (MPa)	45 000 (310)	58 000 (400)	62 000 (427)	58 000 (400)
Yield strength, min, psi (MPa)	39 000 (269)	46 000 (317)	50 000 (345)	36 000 (250)
Elongation in 2 in. (50.8 mm), min, % <sup>A</sup>	25 <sup>B</sup>	23 <sup>C</sup>	21 <sup>D</sup>	23 <sup>C</sup>

<sup>A</sup> The minimum elongation values specified apply only to testing performed prior to shipment because of the possibility of strain aging. Tests performed after shipment may show values below those stated.

<sup>B</sup> Applies to specified wall thicknesses 0.120 in. (3.05 mm) and over. For wall thicknesses under 0.120 in., the minimum elongation shall be calculated by the formula: percent elongation in 2 in. = 56t + 17.5.

<sup>C</sup> Applies to specified wall thicknesses 0.180 in. (4.57 mm) and over. For wall thicknesses under 0.180 in., the minimum elongation shall be calculated by the formula: percent elongation in 2 in. = 61t + 12.

<sup>D</sup> Applies to specified wall thicknesses 0.120 in. (3.05 mm) and over. For lighter wall thicknesses, elongation shall be by agreement with the manufacturer.

NOTE—The following table gives calculated minimum values for longitudinal strip tests:

Wall thickness, in. (mm)	Elongation in 2 in. (50.8 mm), min, %	
	Grade A	Grade B
0.180 (4.57)	...	23
0.165 (4.19)	...	22
0.148 (3.76)	...	21
0.134 (3.40)	...	20
0.120 (3.05)	25	19.5
0.109 (2.77)	23.5	19
0.095 (2.41)	23	18
0.083 (2.11)	22	17
0.065 (1.65)	21	16
0.049 (1.24)	20	15
0.035 (0.89)	19.5	14

or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

9.3 For seamless round structural tubing 2 3/8 in. (60.3 mm) outside diameter and larger, a section not less than 2 1/2 in. (63.5 mm) in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility no cracks or breaks on the inside or outside surfaces, except as provided for in 9.5, shall occur until the distance between the plates is less than the value of "H" calculated by the following equation:

$$H = (1 + e)t / (e + t/D)$$

where:

H = distance between flattening plates, in.,

e = deformation per unit length (constant for a given grade of steel, 0.09 for Grade A, 0.07 for Grade B, and 0.06 for Grade C),

t = nominal wall thickness of tubing, in., and

D = actual outside diameter of tubing, in.

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the tubing meet. Evidence of laminated or

unsound material that is revealed during the entire flattening test shall be cause for rejection.

9.4 Surface imperfections not found in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with Section 14.

9.5 When low *D*-to-*t* ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the *D*-to-*t* ratio is less than 10.

10. Permissible Variations in Dimensions

10.1 Outside Dimensions:

10.1.1 Round Structural Tubing—The outside diameter shall not vary more than ±0.5 % rounded to the nearest 0.005 in. (0.13 mm), of the nominal outside diameter size specified, for nominal outside diameters 1.900 in. (48.26 mm) and smaller, and plus and minus 0.75 % rounded to the nearest 0.005 in. of the nominal outside diameter for nominal outside diameters 2.00 in. (50.8 mm) and larger. The outside diameter measurements shall be made at positions at least 2 in. (50.8 mm) from either end of the tubing.

10.1.2 Square and Rectangular Structural Tubing—The specified dimensions, measured across the flats at positions at least 2 in. (50.8 mm) from either end of the tubing and exceeding an allowance for convexity or concavity, shall not exceed the plus and minus tolerances shown in Table 3.

10.2 Wall Thickness—The minimum wall thickness at any point of measurement on the tubing shall be not more than 10 % less than the nominal wall thickness specified. The maximum wall thickness, excluding the weld seam of welded tubing, shall be not more than 10 % greater than the nominal wall thickness specified. The wall thickness on square and rectangular tubing is to be measured at the center of the flat.

10.3 Length—Structural tubing is normally produced in random mill lengths 5 ft (1.5 m) and over, in multiple lengths, and in specified mill lengths. Refer to Section 3. When specified mill lengths are ordered, the length tolerance shall be in accordance with Table 4.

10.4 Straightness—The permissible variation for straightness of structural tubing shall be 1/8 in. times the

TABLE 3 Outside Dimension Tolerances for Square and Rectangular Structural Tubing

Outside Large Flat Dimension, in. (mm)	Large Flat Dimension Tolerance, <sup>A</sup> plus and minus, in. (mm)
2½ (63.5) or under	0.020 (0.51)
Over 2½ to 3½ (63.5 to 88.9), incl	0.025 (0.64)
Over 3½ to 5½ (88.9 to 139.7), incl	0.030 (0.76)
Over 5½ (139.7)	0.01 times large flat dimension

<sup>A</sup> Tolerances include allowance for convexity or concavity. For rectangular tubing having a ratio of outside large to small flat dimension less than 1.5, and for square tubing, the tolerance on small flat dimension shall be identical to the large flat dimension tolerance. For rectangular tubing having a ratio of outside large to small flat dimension in the range of 1.5 to 3.0 inclusive, the tolerance on small flat dimension shall be 1.5 times the large flat dimension tolerance. For rectangular tubing having a ratio of outside large to small flat dimension greater than 3.0, the tolerance on small flat dimension shall be 2.0 times the large flat dimension tolerance.

TABLE 4 Specified Mill Length Tolerances for Structural Tubing

	22 ft (6.7 m) and Under		Over 22 to 44 ft (6.7 to 13.4 m), incl	
	Over	Under	Over	Under
Length tolerance for specified mill length, in. (mm)	½ (12.7)	¼ (6.4)	¾ (19.0)	¼ (6.4)

number of feet (10.4 mm times the number of metres) of total length divided by 5.

10.5 Squareness of Sides—For square or rectangular structural tubing, adjacent sides may deviate from 90° by a tolerance of ±2° max.

10.6 Radius of Corners—For square or rectangular structural tubing, the radius of any outside corner of the section shall not exceed three times the specified wall thickness.

10.7 Twist—The tolerances for twist or variation with respect to axial alignment of the section, for square and rectangular structural tubing, shall be as shown in Table 5. Twist is measured either by holding down one end of a square or rectangular tube on a flat surface plate with the bottom side of the tube parallel to the surface plate and noting the difference in height above the surface plate of the two corners at the opposite end of the bottom side of the tube or by measuring this difference on the heavier sections by a suitable measuring device. The difference in the height of the corners shall not exceed the values in Table 5. Twist measurements are not to be taken within 2 in. (50 mm) of either end of the product.

11. Special Shape Structural Tubing

11.1 The dimensions and tolerances of special shape structural tubing are available by inquiry and negotiation with the manufacturer.

12. Number of Tests

12.1 One tension test as specified in Section 14 shall be made from a length of tubing representing each lot.

12.2 The flattening test, as specified in Section 9 shall be made on one length of round tubing from each lot.

12.3 The term "lot" applies to all tubes of the same nominal size and wall thickness which are produced from the same heat of steel.

13. Retests

13.1 If the results of the mechanical tests representing any lot do not conform to a requirement as specified in Sections 8 and 9, retests may be made on additional tubing of double

TABLE 5 Twist Tolerances for Square and Rectangular Structural Tubing

Specified Dimension of Longest Side, in. (mm)	Maximum Twist in the First 3 ft (1 m) and in each additional 3 ft	
	in.	mm
1½ (38.1) and under	0.050	1.39
Over 1½ to 2½ (38.1 to 63.5), incl	0.062	1.72
Over 2½ to 4 (63.5 to 101.6), incl	0.075	2.09
Over 4 to 6 (101.6 to 152.4), incl	0.087	2.42
Over 6 to 8 (152.4 to 203.2), incl	0.100	2.78
Over 8 (203)	0.112	3.11

the original number from the same lot, each of which shall conform to the requirement specified, or the tubing represented by the test is subject to rejection.

13.2 In case of failure on retest to meet the requirements of Sections 8 and 9, the manufacturer may elect to retreat, rework, or otherwise eliminate the condition responsible for failure to meet the specified requirements. Thereafter, the material remaining from the lot originally represented may be tested and shall comply with all requirements of this specification.

#### 14. Test Methods

14.1 The tension specimens required by this specification shall conform to those described in the latest issue of Test Methods and Definitions A 370, Annex A 2 on Tubular Products.

14.2 The tension test specimen shall be taken longitudinally from a section of the finished tubing, at a location at least 90° from the weld in the case of welded tubing, and shall not be flattened between gage marks. If desired, the tension tests may be made on the full section of the tubing; otherwise, a longitudinal strip-test specimen as prescribed in Test Methods and Definitions A 370 Supplementary Requirements II shall be used. The specimens shall have all burrs removed and shall not contain surface imperfections which would interfere with proper determination of the tensile properties of the metal.

14.3 The yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen or to a total extension of 0.5 % of the gage length under load shall be determined.

#### 15. Inspection

15.1 All tubing shall be subject to an inspection at place of manufacture to assure conformance to the requirements of this specification.

15.2 All tubing shall be free from defects and shall have a workmanlike finish.

15.2.1 Surface imperfections shall be classed as defects when their depth reduces the remaining wall thickness to less than 90 % of the specified nominal wall. Defects having a depth not in excess of 33 1/3 % of the wall thickness may be repaired by welding, subject to the following conditions:

15.2.1.1 The defect shall be completely removed by chipping or grinding to sound metal,

15.2.1.2 The repair weld shall be made using a low-hydrogen welding process, and

15.2.1.3 The projecting weld metal shall be removed to produce a workmanlike finish.

15.2.2 Surface imperfections such as handling marks, light die or roll marks, or shallow pits are not considered defects providing the imperfections are removable within the minimum wall permitted. The removal of such surface imperfections is not required. Welded tubing shall be free of protruding metal on the outside surface of the weld seam.

15.3 The ends of structural tubing, unless otherwise specified, shall be finished square cut and the burr held to a minimum. The burr can be removed on the outside diameter, inside diameter, or both, as a supplementary requirement. When burrs are to be removed, it shall be specified on the purchase order.

15.4 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the chemical and tensile tests shall be furnished.

#### 16. Rejection

16.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

16.2 Tubing found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such tubing shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

#### 17. Product Marking

17.1 Except as noted in 17.2, each length of structural tubing shall be legibly marked to show the following information: manufacturer's name, brand, or trademark; the specification number; and grade letter.

17.2 For structural tubing having a largest dimension of 4 in. (101.6 mm) or less, the information listed in 17.1 may be marked on a tag securely attached to each bundle.

17.3 *Bar Coding*—In addition to the requirements in 17.1 and 17.2, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

#### 18. Packing, Marking, and Loading

18.1 When specified in the order, contract, etc., packing, marking, and loading shall be in accordance with those procedures of Practices A 700.

#### 19. Government Procurement

19.1 When specified in the contract, material shall be preserved, packaged and packed in accordance with the requirements of MIL-STD 163. The applicable levels shall be as specified in the contract. Marking for shipment of such materials shall be in accordance with Federal Std. No. 123 for civil agencies and MIL-STD 129 or Federal Std. No. 183 if continuous marking is required, for military agencies.

19.2 *Inspection*—Unless otherwise specified in the contract, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the producer may use his own, or any other suitable facilities for performing the inspection and test requirements specified herein, unless otherwise disapproved by the purchaser in the contract or purchase order. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where deemed necessary to ensure that the material conforms to the prescribed requirements.

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