Designation: A500/A500M – 13

Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes[1]

This standard is issued under the fixed designation A500/A500M; 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.

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 periphery of 88 in. [2235 mm] or less, and a specified wall thickness of 0.875 in. [22 mm] or less. 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 either SI units or inch-pound units are to be regarded separately as standard. Within the text, the 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. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

1.4 The text of this specification contains notes and footnotes that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

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:*[2]

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

2.2 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[3]

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage[3]

2.3 *Federal Standards:*

Fed. Std. No. 123 Marking for Shipment[3]

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products[3]

2.4 *AIAG Standard:*

B-1 Bar Code Symbology Standard[4]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A941.

4. Ordering Information

4.1 Orders for material under this specification shall contain information concerning as many of the following items as are required to describe the desired material adequately:

4.1.1 Quantity (feet [metres] or number of lengths),

4.1.2 Name of material (cold-formed tubing),

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.09 on Carbon Steel Tubular Products.

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[2] 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.

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[4] Available from Automotive Industry Action Group (AIAG), 26200 Lahser Rd., Suite 200, Southfield, MI 48033, http://www.aiag.org.

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

4.1.3 Method of manufacture (seamless or welded),
4.1.4 Grade (A, B, C, or D),
4.1.5 Size (outside diameter and wall thickness for round tubing, and outside dimensions and wall thickness for square and rectangular tubing),
4.1.6 Copper-containing steel (see Table 1), if applicable,
4.1.7 Length (random, multiple, specific; see 11.3),
4.1.8 End condition (see 16.3),
4.1.9 Burr removal (see 16.3),
4.1.10 Certification (see Section 18),
4.1.11 ASTM specification designation and year of issue,
4.1.12 End use,
4.1.13 Special requirements, and
4.1.14 Bar coding (see 19.3).

5. Process

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

5.2 When steels of different grades are sequentially strand cast, the steel producer shall identify the resultant transition material and remove it using an established procedure that positively separates the grades.

6. Manufacture

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

6.2 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.

6.3 The weld shall not be located within the radius of the corners of any shaped tube unless specified by the purchaser.

NOTE 2—Welded tubing is normally furnished without removal of the inside flash.

6.4 Except as required by 6.5, it shall be permissible for the tubing to be stress relieved or annealed.

6.5 Grade D tubing shall be heat treated at a temperature of at least 1100 °F [590 °C] for one hour per inch [25 mm] of thickness.

TABLE 1 Chemical Requirements

Element	Composition, %			
	Grades A, B, and D		Grade C	
	Heat Analysis	Product Analysis	Heat Analysis	Product Analysis
Carbon, max[A]	0.26	0.30	0.23	0.27
Manganese, max[A]	1.35	1.40	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, min[B]	0.20	0.18	0.20	0.18

[A] For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 % by heat analysis and 1.60 % by product analysis.
[B] If copper-containing steel is specified in the purchase order.

7. Heat Analysis

7.1 Each heat analysis shall conform to the requirements specified in Table 1 for heat analysis.

8. Product Analysis

8.1 The tubing shall be capable of conforming to the requirements specified in Table 1 for product analysis.

8.2 If product analyses are made, they shall be made using test specimens taken from two lengths of tubing from each lot of 500 lengths, or fraction thereof, or two pieces of flat-rolled stock from each lot of a corresponding quantity of flat-rolled stock. Methods and practices relating to chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A751. Such product analyses shall conform to the requirements specified in Table 1 for product analysis.

8.3 If both product analyses representing a lot fail to conform to the specified requirements, the lot shall be rejected.

8.4 If only one product analysis representing a lot fails to conform to the specified requirements, product analyses shall be made using two additional test specimens taken from the lot. Both additional product analyses shall conform to the specified requirements or the lot shall be rejected.

9. Tensile Requirements

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

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 [425]	58 000 [400]
Yield strength, min, psi [MPa]	33 000 [230]	42 000 [290]	46 000 [315]	36 000 [250]
Elongation in 2 in. [50 mm], min, %[D]	25[A]	23[B]	21[C]	23[B]
Shaped Structural Tubing				
	Grade A	Grade B	Grade C	Grade D
Tensile strength, min, psi [MPa]	45 000 [310]	58 000 [400]	62 000 [425]	58 000 [400]
Yield strength, min, psi [MPa]	39 000 [270]	46 000 [315]	50 000 [345]	36 000 [250]
Elongation in 2 in. [50 mm], min, %[D]	25[A]	23[B]	21[C]	23[B]

[A] Applies to specified wall thicknesses (t) equal to or greater than 0.120 in. [3.05 mm]. For lighter specified wall thicknesses, the minimum elongation values shall be calculated by the formula: percent elongation in 2 in. [50 mm] = $56t + 17.5$, rounded to the nearest percent. For A500M use the following formula: $2.2t + 17.5$, rounded to the nearest percent.
[B] Applies to specified wall thicknesses (t) equal to or greater than 0.180 in. [4.57 mm]. For lighter specified wall thicknesses, the minimum elongation values shall be calculated by the formula: percent elongation in 2 in. [50 mm] = $61t + 12$, rounded to the nearest percent. For A500M use the following formula: $2.4t + 12$, rounded to the nearest percent.
[C] Applies to specified wall thicknesses (t) equal to or greater than 0.120 in. [3.05 mm]. For lighter specified wall thicknesses, the minimum elongation values shall be by agreement with the manufacturer.
[D] The minimum elongation values specified apply only to tests performed prior to shipment of the tubing.

10. Flattening Test

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

10.2 For welded round structural tubing, a test specimen at least 4 in. [100 mm] in length shall be flattened cold between parallel plates in three steps, with the weld located 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 of the test specimen shall be present until the distance between the plates is less than two-thirds of the specified outside diameter of the tubing. For the second step, no cracks or breaks on the inside or outside parent metal surfaces of the test specimen, except as provided for in 10.5, shall be present until the distance between the plates is less than one-half of the specified outside diameter of the tubing. During the third step, which is a test for soundness, the flattening shall be continued until the test specimen breaks or the opposite walls of the test specimen meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

10.3 For seamless round structural tubing 2⅜ in. [60 mm] specified outside diameter and larger, a specimen not less than 2½ in. [65 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 10.5, shall occur until the distance between the plates is less than the value of "H" calculated by the following equation:

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

where:

H = distance between flattening plates, in. [mm],
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 = specified wall thickness of tubing, in. [mm], and
D = specified outside diameter of tubing, in. [mm].

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 specimen meet. Evidence of laminated or unsound material that is revealed during the entire flattening test shall be cause for rejection.

10.4 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 15.

10.5 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.

11. Permissible Variations in Dimensions

11.1 *Outside Dimensions:*

11.1.1 *Round Structural Tubing*—The outside diameter shall not vary more than ±0.5 %, rounded to the nearest 0.005 in. [0.1 mm], from the specified outside diameter for specified outside diameters 1.900 in. [48 mm] and smaller, and ± 0.75 %, rounded to the nearest 0.005 in. [0.1 mm], from the specified outside diameter for specified outside diameters 2.00 in. [5 cm] and larger. The outside diameter measurements shall be made at positions at least 2 in. [5 cm] from the ends of the tubing.

11.1.2 *Square and Rectangular Structural Tubing*—The outside dimensions, measured across the flats at positions at least 2 in. [5 cm] from the ends of the tubing, shall not vary from the specified outside dimensions by more than the applicable amount given in Table 3, which includes an allowance for convexity or concavity.

11.2 *Wall Thickness*—The minimum wall thickness at any point of measurement on the tubing shall be not more than 10 % less than the specified wall thickness. The maximum wall thickness, excluding the weld seam of welded tubing, shall be not more than 10 % greater than the specified wall thickness. For square and rectangular tubing, the wall thickness requirements shall apply only to the centers of the flats.

11.3 *Length*—Structural tubing is normally produced in random lengths 5 ft [1.5 m] and over, in multiple lengths, and in specific lengths. Refer to Section 4. When specific lengths are ordered, the length tolerance shall be in accordance with Table 4.

11.4 *Straightness*—The permissible variation for straightness of structural tubing shall be ⅛ in. times the number of feet [10 mm times the number of metres] of total length divided by 5.

11.5 *Squareness of Sides*—For square and rectangular structural tubing, adjacent sides shall be square (90°), with a permissible variation of ±2° max.

11.6 *Radius of Corners*—For square and rectangular structural tubing, the radius of each outside corner of the section shall not exceed three times the specified wall thickness.

11.7 *Twist*—For square and rectangular structural tubing, the permissible variations in twist shall be as given in Table 5.

TABLE 3 Permissible Variations in Outside Flat Dimensions for Square and Rectangular Structural Tubing

Specified Outside Large Flat Dimension, in. [mm]	Permissible Variations Over and Under Specified Outside Flat Dimensions,[A] in. [mm]
2½ [65] or under	0.020 [0.5]
Over 2½ to 3½ [65 to 90], incl	0.025 [0.6]
Over 3½ to 5½ [90 to 140], incl	0.030 [0.8]
Over 5½ [140]	0.01 times large flat dimension

[A] The permissible variations include allowances for convexity and concavity. For rectangular tubing having a ratio of outside large to small flat dimension less than 1.5, and for square tubing, the permissible variations in small flat dimension shall be identical to the permissible variations in large flat dimension. For rectangular tubing having a ratio of outside large to small flat dimension in the range of 1.5 to 3.0 inclusive, the permissible variations in small flat dimension shall be 1.5 times the permissible variations in large flat dimension. For rectangular tubing having a ratio of outside large to small flat dimension greater than 3.0, the permissible variations in small flat dimension shall be 2.0 times the permissible variations in large flat dimension.