



Designation: A501/A501M – 21

# Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing<sup>1</sup>

This standard is issued under the fixed designation A501/A501M; 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.

## 1. Scope\*

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

1.2 Square and rectangular tubing is produced with flats of 1 to 16 in. [25 to 405 mm] and a specified wall thickness 0.095 to 1.0 in. [2.5 to 25 mm]. Round tubing is produced with diameters of 1 to 48 in. [25 to 1220 mm] and a specified wall thickness of 0.095 to 4.00 in. [2.5 to 100 mm].

1.3 This specification covers three grades: A, B, and C.

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 specification is expressed in both inch-pound units and in SI units; however, unless the purchase order specifies the applicable M specification designation (SI units), the inch-pound units shall apply. 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 nonconformance with the standard.

1.6 *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.*

<sup>1</sup> 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.

Current edition approved Aug. 1, 2021. Published September 2021. Originally approved in 1964. Last previous edition approved in 2014 as A501/A501M – 14. DOI: 10.1520/A0501\_A0501M-21.

## 2. Referenced Documents

2.1 *ASTM Standards*:<sup>2</sup>

A53/A53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

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 and Practices for Chemical Analysis of Steel Products

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

2.2 *AIAG Standard*:<sup>3</sup>

B-1 Bar Code Symbology Standard

2.3 *Federal Standard*:<sup>4</sup>

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)

2.4 *Military Standards*:<sup>4</sup>

MIL-STD-129 Marking for Shipment and Storage

## 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 (weight in metric tons, feet [meters], or number of lengths),

4.1.2 Name of material (hot-formed tubing),

4.1.3 Method of manufacture (seamless or welded); see Section 6,

4.1.4 Grade (A, B, or C),

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from Automotive Industry Action Group (AIAG), 26200 Lahser Rd., Suite 200, Southfield, MI 48033, <http://www.aiag.org>.

<sup>4</sup> Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, <http://www.access.gpo.gov>.

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

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 Finish (black or galvanized),

4.1.7 Length (random, multiple, or specific; see 12.4),

4.1.8 End condition (see 17.5),

4.1.9 Burr removal (see 17.5),

4.1.10 Certification (see Section 19),

4.1.11 ASTM specification designation and year of issue,

4.1.12 Bar coding (see 20.3),

4.1.13 Packaging, package marking, and loading for shipment (see Section 21),

4.1.14 Product analysis (see Supplementary Requirements S2),

4.1.15 End use, and

4.1.16 Special requirements.

## 5. Process

5.1 The steel shall be made by basic-oxygen or electric-arc-furnace steel making process.

5.2 Steel may be cast in ingots or may be strand cast.

5.3 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 one of the following processes: seamless; furnace-butt-welding (continuous welding); electric-resistance welding or submerged arc welding followed by reheating throughout the cross section and hot forming by a reducing or shaping process, or both.

6.2 The final shape formation shall be made by a hot forming process.

6.3 The weld shall not be located within the radius of the corners of any tube having one or more flat sides.

6.4 It shall be permissible to add a normalizing heat treatment for tubing with a wall thickness greater than ½ in. [13 mm].

## 7. Heat Analysis

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

## 8. Product Analysis

8.1 When product analysis is ordered (see 4.1.14 and S2) the tubing shall be capable of conforming to the requirements specified in Table 1.

## 9. Tensile Requirements

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

9.2 The elongation may be determined on a gage length of either 2 in. or 8 in. [50 mm or 200 mm] at the manufacturer's choice.

## 10. Impact Requirements

10.1 The Charpy V-notch impact test specimens shall conform to requirements prescribed in Table 2. Impact tests are not required for thicknesses smaller than or equal to 0.250 in. [6.3 mm], unless specified.

10.2 Charpy V-notch tests shall be made in accordance with Test Methods and Definitions A370. One test shall consist of a set of three specimens. Standard specimens 10 by 10 mm [0.394 by 0.394 in.] in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable subsize specimens shall be used. Acceptance criteria for subsize specimens shall be in accordance with Test Methods and Definitions A370.

10.3 One Charpy V-notch impact test shall be made from a length of tubing representing each lot.

10.4 The test results of standard full-size longitudinal specimens shall meet a minimum average per set of three specimens and minimum single value as specified in Table 2. The specimen axis shall be parallel to the tubing axis and the notch shall be normal to the surface of the material. For wall thicknesses 1.5 in. [38 mm] and less, the specimens shall be located with their surface at least 0.08 in. [2 mm] from the material surface; for wall thicknesses greater than 1.5 in. [38 mm], the specimens shall be located with their surface at least ¼ times the wall thickness from the material surface.

10.5 The maximum test temperature shall be 0°F [–18°C].

## 11. Dimensions

11.1 *Round Structural Tubing*—The dimensions are defined by outside diameter (OD) and the wall thickness (t).

**TABLE 1 Chemical Requirements<sup>A</sup>**

Element	Composition, %			
	Grade A		Grade B, C	
	Heat analysis	Product analysis	Heat analysis	Product analysis
Carbon, max <sup>B</sup>	0.26	0.30	0.22	0.26
Manganese, max <sup>B</sup>	...	...	1.40	1.45
Phosphorus, max	0.035	0.045	0.030	0.040
Sulfur, max	0.035	0.045	0.020	0.030
Copper, when copper steel is specified, min	0.20	0.18	0.20	0.18

<sup>A</sup> Where an ellipsis (...) appears in this table, there is no requirement.

<sup>B</sup> 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 1.60 % by heat analysis and 1.65 % by product analysis.

**TABLE 2 Tensile and Impact Requirements**

	Wall Thickness, in. [mm]	Grade A	Grade B	Grade C
Tensile strength, min, psi [MPa]	All	58 000 [400]	65 000 [448]	70 000 [483]
	≤ 1 [25]	39 000 [270]	46 000 [315]	50 000 [345]
	> 1 [25] and ≤ 2 [50]	38 000 [260]	45 000 [310]	49 000 [340]
Yield strength, min, psi [MPa]	> 2 [50] and ≤ 3 [76]	36 500 [250]	42 500 [290]	47 500 [330]
	> 3 [76] and ≤ 4 [100]	35 000 [240]	40 000 [280]	46 000 [315]
Elongation, min, %		25	24	23
Impact Energy, min. average ft/lbf [J] (see 10.4)		20 [27]	20 [27]	20 [27]
min. single ft/lbf [J] (see 10.4)		14 [19]	14 [19]	14 [19]

11.2 *Square and Rectangular Structural Tubing*—The outside dimensions are defined by length of 1st side (H), length of 2nd side (B), and the wall thickness (t). The nominal weight (W) shall be calculated by the following equation:

$$W = \frac{490(2 t (B + H) - (5.07 t^2))}{144} \quad (1)$$

$$\left[ W = \frac{0.785 (2 t (B + H) - (5.07 t^2))}{100} \right]$$

where:

- W = weight, lb/ft [kg/m]
- H = length of 1st side, or longer side at rectangular dimensions, inch [mm]
- B = length of 2nd side, or shorter side at rectangular dimensions, inch [mm]
- t = wall thickness, inch [mm]

NOTE 1—The resulting corresponding sectional properties should be calculated separately, for example, per ISO 12633-2.

11.3 *Special Shape Structural Tubing*—The dimensions and tolerances of special shape structural tubing are available by inquiry and negotiation with the manufacturer.

## 12. Permissible Variations in Dimensions

### 12.1 Outside Dimensions:

12.1.1 *Round Structural Tubing*—For outside diameter greater than 2 in. [50 mm], the outside diameter shall not vary more than ±1 % from the specified outside diameter. For outside diameter 2 in. [50 mm] and under, the outside diameter shall not vary more than ±1/48 in. [0.50 mm] from the specified outside diameter.

12.1.2 *Square, Rectangular, and Special Shape Structural Tubing*—For outside dimensions greater than 2 in. [50 mm], the outside dimensions, measured across the flats at positions at least 2 in. [50 mm] from the ends of the tubing, shall not vary more than ± 1 % from the specified outside dimension. For outside dimensions 2.0 in. [50 mm] and under, the outside dimension shall not vary more than ± 1/48 in. [0.50 mm] from the specified outside dimension.

12.2 *Wall Thickness*—The wall thickness at any point of measurement of the structural tubing shall vary by no more than –10 % from the specified wall thickness. For square, rectangular, and special shaped structural tubing, the wall thickness requirements shall only apply to the centers of the flats.

12.3 *Weight*—The weight of the structural tubing shall vary by no more than 3.5 % under or 10 % above its nominal weight. For square and rectangular structural tubing, the nominal weight shall be calculated per 12.2.

12.4 *Length*—Structural tubing is commonly produced in random lengths of 16 to 22 ft. [5 to 7 m] or 32 to 44 ft. [10 to 14 m], in multiple lengths, and in specific lengths. When specific lengths are ordered, the permissible variations in length shall be as given in Table 3.

12.5 *Straightness*—The permissible variation for straightness of structural tubing shall be 1/8 in. times the number of feet [10 mm times the number of meters] of total length divided by five.

NOTE 2—It is recommended that for compression members and other applications for which straightness is of particular concern, these requirements be verified, and more stringent requirements be specified if needed.

12.6 *Squareness of Sides*—For square and rectangular tubing, adjacent sides shall be square (90°), with a permissible variation of ±1°.

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

12.8 *Twist*—For square, rectangular, and special shape structural tubing, the permissible variations in twist shall not vary more than 1/12 in. [2.1 mm] plus 1/144 in./ft [0.5 mm/m]. Twist measurements shall not be taken within 2 in. [50 mm] of the ends of the tubing.

NOTE 3—A recommended method for determining twist is to hold one end of the tubing down on a flat surface plate, measure the height that each corner on the bottom side of the tubing extends above the surface plate near the opposite end of the tubing, and calculate the twist (the difference in the measured heights of such corners).

**TABLE 3 Permissible Variations in Length for Specific Lengths of Structural Tubing**

	Specific Length			
	22 ft [7 m] and Under		Over 22 to 44 ft [7 to 14 m], incl	
	Over	Under	Over	Under
Permissible variations in length, in. [mm]	1/2 [13]	1/4 [6]	3/4 [19]	1/4 [6]

12.9 *Concavity and Convexity*—For square, rectangular, and special shape structural tubing, the tolerance for concavity and convexity is 1 % from the specified outside dimension.

### 13. Number of Tests

13.1 One tension test as specified in 15.2 shall be made from a length of tubing representing each lot.

13.2 The term “lot” shall apply to all tubes of the same specified size that are produced from the same heat of steel.

### 14. Retests

14.1 If the results of the mechanical tests representing any lot fail to conform to the applicable requirements specified in Sections 9 and 10, the lot shall be rejected or retested using additional tubing of double the original number from the lot. The lot shall be acceptable if the results of all such retests representing the lot conform to the specified requirements.

14.2 If one or both of the retests specified in 14.1 fail to conform to the applicable requirements specified in Sections 9 and 10, the lot shall be rejected or, subsequent to the manufacturer heat treating, reworking, or otherwise eliminating the condition responsible for the failure, the lot shall be treated as a new lot and tested accordingly.

### 15. Test Method

15.1 Tension test specimens shall conform to the applicable requirements of Test Methods and Definitions A370, Annex A2.

15.2 Tension test specimens shall be full-size longitudinal test specimens or longitudinal strip test specimens. For welded tubing, any longitudinal strip test specimens shall be taken from a location at least 90° from the weld and shall be prepared without flattening in the gauge length. Longitudinal strip test specimens shall have all burrs removed. Tension test specimens shall not contain surface imperfections that would interfere with proper determination of the tensile properties.

15.3 The yield strength corresponding to an offset of 0.2 % of the gauge length or to a total extension under load of 0.5 % of the gauge length shall be determined.

### 16. Galvanized Coatings

16.1 For structural tubing required to be hot-dip galvanized, such coating shall comply with the requirements contained in Specification A53/A53M, except that the manufacturer shall additionally have the option of determining the coating weight/thickness using only the values obtained for the coating on the outside surface of the tubing.

### 17. Inspection

17.1 All tubing shall be inspected at the place of manufacture to ensure conformance with the requirements of this specification.

17.2 The structural tubing shall be free of defects and shall have a smooth finish resulting from the hot rolling manufacturing process.

17.3 Surface imperfections shall be classed as defects when the depth of the imperfections exceeds 10 % of the nominal wall thickness.

17.4 Welded repair shall only be permitted when the depth of the imperfection does not exceed 10 % of the nominal wall thickness and is agreed to between the purchaser and the producer. Imperfections to be repaired shall be completely removed by chipping or grinding prior to welding.

17.5 Unless otherwise specified in the purchase order, structural tubing shall be furnished with square cut ends. The burr shall be held to a minimum. When so specified in the purchase order, the burr shall be removed on the outside diameter, inside diameter, or both.

### 18. Rejection

18.1 It shall be permissible for the purchaser to inspect tubing received from the manufacturer and reject any tubing that does not meet the requirements of this specification, based upon the inspection and test methods outlined herein. The purchaser shall notify the manufacturer of any tubing that has been rejected, and the disposition of such tubing shall be subject to agreement between the manufacturer and the purchaser.

18.2 It shall be permissible for the purchaser to set aside any tubing that is found in fabrication or installation within the scope of this specification to be unsuitable for the intended end use, based on the requirements of this specification. The purchaser shall notify the manufacturer of any tubing that has been set aside. Such tubing shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation conditions, or both, involved. The disposition of such tubing shall be subject to agreement between the manufacturer and the purchaser.

### 19. Certification

19.1 When specified in the purchase order or contract, the manufacturer shall furnish to the purchaser a certificate of compliance stating that the product was manufactured, sampled, tested, and inspected in accordance with this specification and any other requirements designated in the purchase order or contract, and was found to meet all such requirements. Certificates of compliance shall include the specification number and year of issue.

19.2 When specified in the purchase order or contract, the manufacturer shall furnish to the purchaser test reports for the product shipped that contain the heat analyses and the results of the tension tests required by this specification and the purchase order or contract. Test reports shall include the specification number and year of issue.

19.3 A signature or notarization is not required on certificates of compliance or test reports; however, the documents shall clearly identify the organization submitting them. Notwithstanding the absence of a signature, the organization submitting the document is responsible for its content.

19.4 A certificate of compliance or test report printed from, or used in electronic form from, an electronic data interchange