



# 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 standard has been approved for use by agencies of 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 standard. The values given in parentheses are mathematical conversions of the values in inch-pound units to values in SI units.

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.

## 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>

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys<sup>4</sup>

### 2.2 Military Standards:

MIL-STD-129 Marking for Shipment and Storage<sup>5</sup>

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage<sup>5</sup>

### 2.3 Federal Standards:

Fed. Std. No. 123 Marking for Shipment<sup>5</sup>

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products<sup>5</sup>

### 2.4 AIAG Standard:

B-1 Bar Code Symbology Standard<sup>6</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A 941.

## 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 or number of lengths),

4.1.2 Name of material (cold-formed tubing),

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 nominal wall thickness for round tubing and the outside dimensions and nominal wall thickness for square and rectangular tubing),

4.1.6 Length (random, multiple, specific; see 11.3),

4.1.7 End condition (see 16.3),

4.1.8 Burr removal (see 16.3),

4.1.9 Certification (see Section 18),

4.1.10 ASTM specification designation and year of issue,

4.1.11 End use,

4.1.12 Special requirements, and

4.1.13 Bar Coding (see 19.3).

## 5. Process

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

5.2 When steels of different grades are sequentially strand cast, the steel producer shall identify the resultant transition

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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> Annual Book of ASTM Standards, Vol 01.01.

<sup>5</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

<sup>6</sup> Available from Automotive Industry Action Group, 26200 Lahser Road, Suite 200, Southfield, MI 48034.

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.

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

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

6.4 Grade D tubing shall be heat treated at a temperature of at least 1100° F (590° C) for one hour per inch (25.4 mm) of thickness.

**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 A 751. 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<br>(310) | 58 000<br>(400) | 62 000<br>(427) | 58 000<br>(400) |
| Yield strength, min, psi (MPa)                     | 33 000<br>(228) | 42 000<br>(290) | 46 000<br>(317) | 36 000<br>(250) |
| Elongation in 2 in. (50.8 mm), min, % <sup>D</sup> | 25 <sup>A</sup> | 23 <sup>B</sup> | 21 <sup>C</sup> | 23 <sup>B</sup> |
| Shaped Structural Tubing                           |                 |                 |                 |                 |
|  | Grade A         | Grade B         | Grade C         | Grade D         |
| Tensile strength, min, psi (MPa)                   | 45 000<br>(310) | 58 000<br>(400) | 62 000<br>(427) | 58 000<br>(400) |
| Yield strength, min, psi (MPa)                     | 39 000<br>(269) | 46 000<br>(317) | 50 000<br>(345) | 36 000<br>(250) |
| Elongation in 2 in. (50.8 mm), min, % <sup>D</sup> | 25 <sup>A</sup> | 23 <sup>B</sup> | 21 <sup>C</sup> | 23 <sup>B</sup> |

The following table gives calculated minimum values for longitudinal strip tests; where an ellipsis (...) appears in this table, there is no requirement

| 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      |

<sup>A</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>B</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>C</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.

<sup>D</sup>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 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 10.5, 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 or unsound material or of incomplete

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

| 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             |

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

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

10.3 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 10.5, shall occur until the distance between the plates is less than the value of “H” calculated by the following equation:

$$H = (1 + e)t / (e + t / D) \tag{1}$$

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.

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. (0.13 mm), of the nominal outside diameter size specified, for nominal outside diameters 1.900 in. (48.3 mm) and smaller, and ± 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 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. (50.8 mm) 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 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. 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

**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) |
|---|---|
| 2 1/2 (63.5) or under                     | 0.020 (0.51)  |
| Over 2 1/2 to 3 1/2 (63.5 to 88.9), incl  | 0.025 (0.64)  |
| Over 3 1/2 to 5 1/2 (88.9 to 139.7), incl | 0.030 (0.76)  |
| Over 5 1/2 (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.

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 1/8 in. times the number of feet (10.4 mm times the number of metres) of total length divided by 5.

11.5 *Squareness of Sides*—For square or 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 nominal wall thicknesses specified.

11.7 *Twist*—For square and rectangular structural tubing, the permissible variations in twist shall be as given in Table 5. Twist shall be determined by holding one end of the tubing down on a flat surface plate, measuring the height that each corner on the bottom side of the tubing extends above the surface plate near the opposite ends of the tubing, and calculating the twist (the difference in heights of such corners), except that for heavier sections it shall be permissible to use a suitable measuring device to determine twist. Twist measurements shall not be taken within 2 in. (50.8 mm) of the ends of the tubing.

**12. Special Shape Structural Tubing**

12.1 The availability, dimensions, and tolerances of special shape structural tubing shall be subject to inquiry and negotiation with the manufacturer.

**13. Number of Tests**

13.1 One tension test as specified in Section 15 shall be

**TABLE 4 Length Tolerances for Specific Lengths of 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 specific length, in. (mm) | 1 / 2 (12.7)            | 1 / 4 (6.4) | 3 / 4 (19.0)                           | 1 / 4 (6.4) |

**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 (203.3)                                | 0.112   | 3.11 |

made from a length of tubing representing each lot.

13.2 The flattening test, as specified in Section 10, shall be made on one length of round tubing from each lot.

13.3 The term "lot" shall apply to all tubes of the same nominal size and wall thickness 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 Methods

15.1 Tension test specimens shall conform to the applicable requirements of Test Methods and Definitions A 370, 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 gage 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 gage length or to a total extension under load of 0.5 % of the gage length shall be determined.

#### 16. Inspection

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

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

16.2.1 Surface imperfections shall be classed as defects when their depth reduces the remaining wall thickness to less than 90 % of the specified nominal wall thickness. It shall be

permissible for defects having a depth not in excess of 33⅓ % of the nominal wall thickness to be repaired by welding, subject to the following conditions:

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

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

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

16.2.2 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.

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

#### 17. Rejection

17.1 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.

17.2 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, or both, conditions involved. The disposition of such tubing shall be subject to agreement between the manufacturer and the purchaser.

#### 18. Certification

18.1 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.

18.2 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.

18.3 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.

18.4 A certificate of compliance or test report printed from, or used in electronic form from, an electronic data interchange (EDI) shall be regarded as having the same validity as a counterpart printed in the certifying organization's facility. The content of the EDI transmitted document shall conform to any existing EDI agreement between the purchaser and the manufacturer.

## 19. Product Marking

19.1 Except as noted in 19.2, each length of structural tubing shall be legibly marked to show the following information: manufacturer's name, brand, or trademark; the specification designation (year of issue not required); and grade letter.

19.2 For structural tubing having a nominal outside diameter or large flat dimension of 4 in. (101.6 mm) or less, it shall be permissible for the information listed in 19.1 to be marked on a tag securely attached to each bundle.

19.3 *Bar Coding*—In addition to the requirements in 19.1 and 19.2, the manufacturer shall have the option of using bar coding as a supplementary identification method. When a specific bar coding system is specified in the purchase order, that system shall be used.

NOTE 3—In the absence of another bar coding system being specified in the purchase order, it is recommended that bar coding be consistent with AIAG Standard B-1.

## 20. Packing, Marking, and Loading

20.1 When specified in the purchase order, packaging, marking, and loading shall be in accordance with Practices A 700.

## 21. Government Procurement

21.1 When specified in the contract, material shall be preserved, packaged and packed in accordance with the requirements of MIL-STD 163, with applicable levels being 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.

21.2 *Inspection*—Unless otherwise specified in the contract, the manufacturer shall be responsible for the performance of all applicable inspection and test requirements specified herein. Except as otherwise specified in the contract, the manufacturer shall use its own or any other suitable facilities for the performance of such inspections and tests.

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