



Designation: A618/A618M – 21

Standard Specification for Hot-Formed Welded and Seamless High-Strength Low-Alloy Structural Tubing¹

This standard is issued under the fixed designation A618/A618M; 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 specification covers grades of hot-formed welded and seamless high-strength low-alloy square, rectangular, round, or special shape structural tubing for welded, riveted, or bolted construction of bridges and buildings and for general structural purposes. When the steel is used in welded construction, the welding procedure shall be suitable for the steel and the intended service.

1.2 Square and rectangular tubing is produced with flats of 1 in. to 16 in. [25 mm to 405 mm] and a specified wall thickness of 0.095 in. to 1.0 in. [2.5 mm to 25 mm]. Round tubing is produced with diameters of 1 in. to 48 in. [25 mm to 1220 mm] and a specified wall thickness of 0.095 in. to 2.50 in. [2.5 mm to 65 mm].

1.3 This specification covers the following grades: Ia, Ib, II, III, IV, V, VI and VII.

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.

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 and Practices for Chemical Analysis of Steel Products

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

G101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels

2.2 *Federal Standard:*³

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

2.3 *Military Standard:*³

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 should include the following as required to describe the material adequately:

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

4.1.2 Name of the material (hot-formed tubing),

4.1.3 Method of manufacture (seamless or welded),

4.1.4 Grade (Ia, Ib, II, III, IV, V, VI or VII),

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

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

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, or specific; see 12.4),

4.1.7 End condition (see 16.5),

4.1.8 Burr removal (see 16.5),

4.1.9 Certification (see Section 18),

4.1.10 Packaging, package marking, and loading for shipment (see Section 20),

4.1.11 Product analysis (see Supplementary Requirements S1),

4.1.12 Specification designation (A618 or A618M, including year date),

4.1.13 End use, and

4.1.14 Special requirements.

5. Process

5.1 The steel shall be made by basic-oxygen, or electric-arc-furnace steelmaking 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, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

6. Manufacture

6.1 The tubing shall be made by the seamless, furnace-butt-welded (continuous-welded), or hot-stretch-reduced electric-resistance-welded process.

6.2 The final cross section 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 for tubing with a wall thickness greater than ½ in. [13 mm] to add a normalizing heat treatment.

6.5 A quenching and tempering process shall be used for Grade V, Grade VI and Grade VII and may be used for Grade IV.

7. Heat Analysis

7.1 When subjected to heat analysis the steel shall conform to the requirements prescribed in Table 1.

7.1.1 For Grades Ia and Ib, the choice and use of alloying elements, combined with carbon, manganese, and sulfur within the limits prescribed in Table 1 to give the mechanical properties prescribed in Table 2 and to provide atmospheric corrosion resistance, should be made by the manufacturer and included and reported in the heat analysis for information purposes only to identify the type of steel applied. For Grades Ia and Ib material, the atmospheric corrosion-resistance index, calculated on the basis of the chemical composition of the steel as described in Guide G101, shall be 6.0 or higher.

NOTE 1—The user is cautioned that the Guide G101 predictive equation for calculation of an atmospheric corrosion-resistance index has been verified only for the composition limits stated in that guide.

7.1.2 When Grade III is required for enhanced corrosion resistance, copper limits may be specified and the minimum content shall be 0.20 % by heat analysis and 0.18 % by product analysis.

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<https://standards.iteh.ai/catalog/standards/sist/c81a9c1-019-46ce-b4a6-bb8f5b1e5a8/astm-a618-a618m-21>

TABLE 1 Chemical Requirements^A

Element	Composition, %															
	Grade Ia		Grade Ib		Grade II		Grade III		Grade IV		Grade V ^E		Grade VI ^F		Grade VII ^F	
	Heat	Product	Heat	Product	Heat	Product	Heat	Product	Heat	Product	Heat	Product	Heat	Product	Heat	Product
Carbon, max	0.15	0.18	0.20	...	0.22	0.26	0.23 ^B	0.27 ^B	0.22	0.25	0.25	0.27	0.20	0.22	0.20	0.22
Manganese, max	1.00	1.04	1.35	1.40	1.25	1.30	1.35 ^B	1.40 ^B	1.6	1.65	1.6	1.65	1.7	1.7	1.75	1.75
Phosphorus, max	0.15	0.16	0.025	0.035	0.025	0.035	0.025	0.035	0.025	0.030	0.025	0.030	0.025	0.030	0.025	0.030
Sulfur, max	0.025	0.045	0.025	0.035	0.025	0.035	0.025	0.035	0.020	0.025	0.020	0.025	0.020	0.025	0.020	0.025
Silicon, max	...	...	...	...	0.30	0.33	0.30	0.35	0.60	0.60	0.60	0.60	0.50	0.50	0.50	0.50
Copper, min	0.20	0.18	0.20 ^C	0.18 ^C	0.20	0.18	...	...	...	...	...	...	...	...	...	...
Vanadium, min	...	...	...	...	0.02	0.01	0.02 ^D	0.01 ^D	0.05	0.04	0.05	0.04	0.05	0.05	0.05	0.05
Chromium, min	...	...	...	...	...	...	...	...	...	...	...	...	0.10	0.10	0.20	0.20
Molybdenum, min	...	...	...	...	...	...	...	...	...	...	...	...	0.10	0.10	0.20	0.20

^A Where an ellipsis (...) appears in this table, there is no requirement.

^B For each reduction of 0.01 % C below the specified carbon maximum, an increase of 0.05 % manganese above the specified maximum will be permitted up to 1.45 % for the heat analysis and up to 1.50 % for the product analysis.

^C If chromium and silicon contents are each 0.50 % min, then the copper minimums do not apply.

^D Columbium may be used in conformance with the following limits: 0.005 %, min (heat) and 0.004 %, min (product).

^E Boron may be used up to a max. 0.0040 %.

^F Other alloying elements, like tungsten, columbium or nickel, may also be used.

TABLE 2 Tensile and Impact Requirements

	Thickness in. [mm]	Grades Ia, Ib, and II ^A	Grade III	Grade IV	Grade V	Grade VI	Grade VII
Tensile strength, min, psi [MPa]	≤ ¾ [19]	70 000 [485]	65 000 [450]	80 000 [550]	100 000 [690]	112 000 [770]	139 000 [960]
	> ¾ [19] and ≤ 1 ½ [38]	67 000 [460]	65 000 [450]	78 000 [540]	100 000 [690]	104 000 [720]	133 000 [920]
	> 1 ½ [38] and ≤ 2 ½ [65]	–	–	78 000 [540]	90 000 [620]	99 000 [680]	125 000 [860]
Yield strength, min, psi [MPa]	≤ ¾ [19]	50 000 [345]	50 000 [345]	67 000 [460]	90 000 [620]	100 000 [690]	129 000 [890]
	> ¾ [19] and ≤ 1 ½ [38]	46 000 [315]	–	64 000 [440]	84 000 [580]	94 000 [650]	123 000 [850]
	> 1 ½ [38] and ≤ 2 ½ [65]	–	–	62 000 [430]	73 000 [500]	84 000 [580]	116 000 [800]
Elongation in 2 in. or 50 mm, min, %	All	22	20	19	18	17	16
Elongation in 8 in. or 200 mm, min, %	All	19	18	17	16	15	14
Impact Energy, min. average ft/lbf [J] min. single ft/lbf [J] (see 10.4)		–	20 [27]	20 [27]	20 [27]	20 [27]	20 [27]
		–	14 [19]	14 [19]	14 [19]	14 [19]	14 [19]

^A For Grade II, when the material is normalized, the minimum yield strength and minimum tensile strength required shall be reduced by 5 ksi [35 MPa].

8. Product Analysis

8.1 When product analysis is ordered (see 4.1.11 and S1) the tubing shall conform 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 Elongation may be determined on a gage length of either 2 in. [50 mm] or 8 in. [200 mm] at the manufacturer's choice.

10. Impact Requirements

10.1 For Grades III, IV, V, VI, VII the Charpy V-notch impact test specimens shall conform to the 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 mm by 10 mm [0.394 in. 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 axial plane 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).

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:

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

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

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 2—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. Dimensions and Permissible Variations

12.1 Outside Dimensions:

12.1.1 *Round Structural Tubing*—For outside diameter greater than 2.0 in [50 mm], the outside diameter shall not vary more than ±1 % from the specified outside diameter. For outside diameter 2.0 in. [50 mm] and under, the outside diameter shall not vary more than ±¼₈ in. [0.50 mm] from the specified outside diameter.

12.1.2 *Square, Rectangular, and Special Shape Structural Tubing*—The outside dimensions are measured across the flats at positions 2.0 in. [50 mm] from the ends of the tubing. For outside dimensions greater than 2.0 in. [50 mm], the outside dimensions 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 $\pm 1/48$ 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 **11.2**.

12.4 Length—Structural tubing is commonly produced in random lengths of 16 ft to 22 ft [5 m to 7 m] or 32 ft 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 5.

NOTE 3—It is recommended that for compression members and other applications for which straightness is of particular concern more stringent requirements shall be specified.

12.6 Squareness of Sides—For square and rectangular structural tubing, adjacent sides shall be square (90°), with a permissible variation of $\pm 1^\circ$.

12.7 Radius of Corners—For square, rectangular, and special shape structural tubing, the radius of any 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. + $1/144$ in./ft [2.1 mm + 0.5 mm/m]. Twist measurements shall not be taken within 2 in. [50 mm] of the ends of the tubing.

NOTE 4—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).

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.

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 m 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]

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 gage length shall be determined.

16. Inspection

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

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

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

16.4 Repair by welding 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.

16.5 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.

17. Rejection

17.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the