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Standard Specification for Seamless Stainless Steel Mechanical Tubing[1]

This standard is issued under the fixed designation A511/A511M; 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 seamless stainless tubing for use in mechanical applications where corrosion-resistant or high-temperature strength is needed. The grades covered are listed in Table 1, Table 2, and Table 3.

1.2 This specification covers seamless cold-finished mechanical tubing and seamless hot-finished mechanical tubing in sizes up to 12¾ in. [325 mm] in outside nominal diameter (for round tubing) with wall thicknesses as required.

1.3 Tubes shall be furnished in one of the following shapes, as specified by the purchaser: round, square, rectangular, or special.

1.4 Optional supplementary requirements are provided and when desired, shall be stated in the order.

1.5 The values stated in inch-pound units are to be regarded as the standard. Within the text, the SI units are shown in square brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A1016/A1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E59 Practice for Sampling Steel and Iron for Determination of Chemical Composition (Withdrawn 1996)[3]

2.2 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[4]

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[4]

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[4]

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, mass, or number of pieces),

3.1.2 Name of material (seamless stainless steel mechanical tubing),

3.1.3 Form (round, square, rectangular, special, see Section 1),

3.1.4 Dimensions (round, outside diameter and wall thickness, see Section 9; square and rectangular, outside dimensions and wall thickness, see Section 10; other, specify),

3.1.5 Length (specific or random, see 9.3),

3.1.6 Manufacture (cold- or hot-finished, see 4.5),

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[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 A01.10 on Stainless and Alloy 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] The last approved version of this historical standard is referenced on www.astm.org.

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

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

TABLE 1 Chemical Requirements of Austenitic Stainless Steels

Grade	Composition, %										
	Carbon	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Titanium	Columbium ~~plus Tantalum~~	Selenium
MT 302	0.08 to 0.20	2.00	0.040	0.030	1.00	8.0–10.0	17.0–19.0	...	...	...	...
MT 303	0.15 max	2.00	0.20	0.15 min	1.00	8.0–10.0	17.0–19.0	...	...	...	...
MT 303Se	0.15 max	2.00	0.040	0.040	1.00	8.0–11.0	17.0–19.0	...	...	...	0.12–0.2
MT 304	0.08 max	2.00	0.040	0.030	1.00	8.0–11.0	18.0–20.0	...	...	...	...
MT 304L	0.035 max[A]	2.00	0.040	0.030	1.00	8.0–13.0	18.0–20.0	...	...	...	...
MT 305	0.12	2.00	0.040	0.030	1.00	10.0–13.0	17.0–19.0	...	...	...	...
MT 309S	0.08 max	2.00	0.040	0.030	1.00	12.0–15.0	22.0–24.0	...	...	...	...
MT 310S	0.08 max	2.00	0.040	0.030	1.00	19.0–22.0	24.0–26.0	...	...	...	...
MT 316	0.08 max	2.00	0.040	0.030	1.00	11.0–14.0	16.0–18.0	2.0–3.0	...	...	...
MT 316L	0.035 max[A]	2.00	0.040	0.030	1.00	10.0–15.0	16.0–18.0	2.0–3.0	...	...	...
MT 317	0.08 max	2.00	0.040	0.030	1.00	11.0–14.0	18.0–20.0	3.0–4.0	...	...	...
~~MT 321~~	~~0.08 max~~	~~2.00~~	~~0.040~~	~~0.030~~	~~1.00~~	~~9.0–13.0~~	~~17.0–20.0~~	~~...~~	~~...~~[B]	~~...~~	~~...~~
~~MT 347~~	~~0.08 max~~	~~2.00~~	~~0.040~~	~~0.030~~	~~1.00~~	~~9.0–13.0~~	~~17.0–20.0~~	~~...~~	~~...~~	~~...~~[C]	~~...~~

TABLE 1 Chemical Requirements of Austenitic Stainless Steels

Grade	Composition, %											
	Carbon	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Titanium	Columbium	Selenium	Iron	Other Elements
MT 302	0.08 to 0.20	2.00	0.040	0.030	1.00	8.0–10.0	17.0–19.0	...	...	...	...	...	...
MT 303	0.15 max	2.00	0.20	0.15 min	1.00	8.0–10.0	17.0–19.0	...	...	...	...	...	...
MT 303Se	0.15 max	2.00	0.040	0.040	1.00	8.0–11.0	17.0–19.0	...	...	...	0.12–0.2	...	...
MT 304	0.08 max	2.00	0.040	0.030	1.00	8.0–11.0	18.0–20.0	...	...	...	...	...	...
MT 304L	0.035 max[A]	2.00	0.040	0.030	1.00	8.0–13.0	18.0–20.0	...	...	...	...	...	...
MT 305	0.12	2.00	0.040	0.030	1.00	10.0–13.0	17.0–19.0	...	...	...	...	...	...
MT 309S	0.08 max	2.00	0.040	0.030	1.00	12.0–15.0	22.0–24.0	...	...	...	...	...	...
MT 310S	0.08 max	2.00	0.040	0.030	1.00	19.0–22.0	24.0–26.0	...	...	...	...	...	...
MT 316	0.08 max	2.00	0.040	0.030	1.00	11.0–14.0	16.0–18.0	2.0–3.0	...	...	...	...	...
MT 316L	0.035 max[A]	2.00	0.040	0.030	1.00	10.0–15.0	16.0–18.0	2.0–3.0	...	...	...	...	...
MT 317	0.08 max	2.00	0.040	0.030	1.00	11.0–14.0	18.0–20.0	3.0–4.0	...	...	...	...	...
MT 321	0.08 max	2.00	0.040	0.030	1.00	9.0–13.0	17.0–20.0	...	5XC – 0.60	...	...	...	...
MT 347	0.08 max	2.00	0.040	0.030	1.00	9.0–13.0	17.0–20.0	...	...	10XC – 1.00	...	...	...
N08020	0.070 max	2.00	0.045	0.035	1.00	32.0–38.0	19.0–21.0	2.00–3.00	...	8XC – 1.00	...	...	Cu 3.00–4.00
N08367	0.030 max	2.00	0.040	0.030	1.00	23.5–25.5	20.0–22.0	6.00–7.00	...	...	...	...	N 0.18–0.25 Cu 0.75
N08800	0.10 max	1.50	0.045	0.015	1.00	30.0–35.0	19.0–23.0	...	0.15–0.60	...	...	39.5 min[B]	Al 0.15–0.60 Cu 0.75
N08810	0.05–0.10	1.50	0.045	0.015	1.00	30.0–35.0	19.0–23.0	...	0.15–0.60	...	...	39.5 min[B]	Al 0.15–0.60 Cu 0.75
N08811	0.06–0.10	1.50	0.045	0.015	1.00	30.0–35.0	19.0–23.0	...	0.25–0.60[C]	...	...	39.5 min[B]	Al 0.25–0.60[C] Cu 0.75
N08904	0.020 max	2.00	0.040	0.030	1.00	23.0–28.0	19.0–23.0	4.0–5.0	...	...	...	...	N 0.10 Cu 1.00–2.00
N08925	0.020 max	1.00	0.045	0.030	0.50	24.0–26.0	19.0–21.0	6.0–7.0	...	...	...	...	N 0.10–0.20 Cu 0.80–1.50
N08926	0.020 max	2.00	0.030	0.010	0.50	24.0–26.0	19.0–21.0	6.0–7.0	...	...	...	...	N 0.15–0.25 Cu 0.40–1.50

[A] For small diameter or thin wall tubing or both, where many drawing passes are required, a maximum of 0.040 % carbon is necessary in grades MT-304L and MT-316L. Small outside diameter tubes are defined as those under a 0.500 in. [12.7 mm] outside diameter and light-wall tubes as those under a 0.049 in. [1.2 mm] average wall thickness (0.044 in. [1.1 mm] min wall thickness).

[B] ~~The titanium content shall be not less than five times the carbon content and not more than 0.60 %.~~ Iron shall be determined arithmetically by difference of 100 minus the sum of the other specified elements.

[C]The ~~columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.00 %.~~range of (Al + Ti) shall be within 0.85–1.20 %.

TABLE 2 Chemical Requirements of Ferritic and Martensitic Stainless Steels

Grade	Composition, %											
	Carbon, max	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Aluminum	Copper	Nitrogen	Selenium
Martensitic												
MT 403	0.15	1.00	0.040	0.030	0.50	0.50 max	11.5–13.0	0.60 max				
MT 410	0.15	1.00	0.040	0.030	1.00	0.50 max	11.5–13.5	...	...	...	...	...
MT 414	0.15	1.00	0.040	0.030	1.00	1.25–2.50	11.5–13.5	...	...	...	...	...
MT 416Se	0.15	1.25	0.060	0.060	1.00	0.50 max	12.0–14.0	...	...	...	...	0.12–0.20
MT 431	0.20	1.00	0.040	0.030	1.00	1.25–2.50	15.0–17.0	...	...	...	...	...
MT 440A	0.60 to 0.75	1.00	0.040	0.030	1.00	...	16.0–18.0	0.75 max	...	...	...	...
Ferritic												
MT 405	0.08	1.00	0.040	0.030	1.00	0.50 max	11.5–14.5	...	0.10–0.30	...	...	...
MT 429	0.12	1.00	0.040	0.030	1.00	0.50 max	14.0–16.0	...	...	...	...	...
MT 430	0.12	1.00	0.040	0.030	1.00	0.50 max	16.0–18.0	...	...	...	...	...
MT 443	0.20	1.00	0.040	0.030	1.00	0.50 max	18.0–23.0	...	...	0.90–1.25	...	...
MT 446–1	0.20	1.50	0.040	0.030	1.00	0.50 max	23.0–30.0	...	...	...	0.25 max	...
MT 446–2[A]	0.12	1.50	0.040	0.030	1.00	0.50 max	23.0–30.0	...	...	...	0.25 max	...
29-4	0.010	0.30	0.025	0.020	0.20	0.15 max	28.0–30.0	3.5–4.2	...	0.15 max	0.020 max	...
29-4-2	0.010	0.30	0.025	0.020	0.20	2.0–2.5	28.0–30.0	3.5–4.2	...	0.15 max	0.020 max[B]	...

[A]MT446-2 is a lower carbon version of MT446-1, that has a lower tensile strength but improved ductility and toughness.
[B]Carbon plus nitrogen = 0.025 max %.

TABLE 3 Chemical Requirements of Austenitic-Ferritic Stainless Steels[A]

Grade	Composition, %										
	Carbon	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Nitrogen	Copper	Others
S31260	0.030	1.00	0.030	0.030	0.75	5.5–7.5	24.0–26.0	2.5–3.5	0.10–0.30	0.20–0.80	W 0.10–0.50
S31803	0.030	2.00	0.030	0.020	1.00	4.5–6.5	21.0–23.0	2.5–3.5	0.08–0.20	...	...
S32101	0.040	4.0–6.0	0.040	0.030	1.00	1.35–1.70	21.0–22.0	0.10–0.80	0.20–0.25	0.10–0.80	...
S32205	0.030	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5	0.14–0.20	...	...
S32304	0.030	2.50	0.040	0.040	1.00	3.0–5.5	21.5–24.5	0.05–0.60	0.05–0.20	0.05–0.60	...
S32506	0.030	1.00	0.040	0.015	0.90	5.5–7.2	24.0–26.0	3.0–3.5	0.08–0.20	...	W 0.05–0.30
S32550	0.040	1.50	0.040	0.030	1.00	4.5–6.5	24.0–27.0	2.9–3.9...	0.10–0.25	1.50–2.50	...
S32707	0.030	1.50	0.035	0.010	0.50	5.5–9.5	26.0–29.0	4.0–5.0	0.30–0.50	1.0	Co 0.5–2.0
S32750	0.030	1.20	0.035	0.020	0.80	6.0–8.0	24.0–26.0	3.0–5.0	0.24–0.32	0.50	...
S32760[B]	0.05	1.00	0.030	0.010	1.00	6.0–8.0	24.0–26.0	3.0–4.0	0.20–0.30	0.50–1.00	W 0.50–1.00
S32906	0.030	0.80-1.50	0.030	0.030	0.80	5.8–7.5	28.0–30.0	1.50–2.60	0.30–0.40	0.80	...
S32808	0.030	1.10	0.030	0.010	0.50	7.0–8.2	27.0–27.9	0.80–1.20	0.30–0.40	...	W 2.10–2.50
S32950	0.030	2.00	0.035	0.010	0.60	3.5–5.2	26.0–29.0	1.00–2.50	0.15–0.35	...	...
S39274	0.030	1.00	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.5–3.5	0.24–0.32	0.20–0.80	W 1.50–2.50

[A]Maximum, unless a range or minimum is indicated. Where ellipses (...) appear in this table, there is no requirement and analysis for the element need not be determined or reported.
[B]% Cr + 3.3 X % Mo + 16X % N ≥ 40.

3.1.7 Grade (Section 6),
3.1.8 Condition (annealed, as cold worked, or with special heat treatment, controlled microstructural characteristics, or other condition as required, see Section 5),
3.1.9 Surface finish (special pickling, shot blasting, or polishing, as required, see Supplementary Requirement S5),
3.1.10 Specification designation,
3.1.11 Report of Chemical Analysis, if required (Sections 7 and 8),
3.1.12 Individual supplementary requirements, if required,
3.1.13 End use,
3.1.14 Packaging,
3.1.15 Special marking (see 15.2),
3.1.16 Special packing (see 16.2), and
3.1.17 Special requirements.

4. Materials and Manufacture

4.1 The steel may be made by any process.

4.2 If a specific type of melting is required by the purchaser, it shall be as stated on the purchase order.

4.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, such as electroslag remelting or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

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

4.5 The tubes shall be made by a seamless process and by either cold working or hot working as specified. Seamless steel tubing is a tubular product made without a welded seam. It is usually manufactured by hot working steel and then cold finishing the hot-worked tubing to produce the desired shape, dimensions, and properties.

5. Condition

5.1 Round seamless stainless mechanical tubing is generally supplied in the cold-worked and annealed condition (see 5.2 through 5.5). Square, rectangular, or other shapes of tubing are generally supplied annealed prior to final cold shaping. If some other condition is desired, details shall be included in the order.

5.2 The thermal treatment for ferritic and martensitic steels shall be performed by a method and at a temperature selected by the manufacturer unless otherwise specified by the purchaser.

5.3 Unless otherwise specified, all austenitic tubes shall be furnished in the annealed condition. ~~The~~ Unless otherwise specified in Table 4, the anneal shall consist of heating the material to a minimum temperature of 1900 °F [1040 °C] and quenching in water or rapidly cooling by other means. Alternatively, immediately following hot forming while the temperature of the tubes is not less than the specified minimum solution treatment temperature, tubes may be individually quenched in water or rapidly cooled by other means. This anneal shall precede final cold work, when cold-worked tempers are required.

5.4 All austenitic-ferritic tubes shall be furnished in the annealed condition as prescribed in Table ~~4~~5. Alternatively, immediately following hot forming, while the temperature of the tubes is not less than the specified minimum solution treatment temperature, tubes may be individually quenched in water or rapidly cooled by other means.

5.5 If any controlled microstructural characteristics are required, these shall be specified so as to be a guide to the most suitable heat treatment.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1, Table 2, or Table 3. Other grades are available.

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified. When requested in the order or contract, a report of this analysis shall be furnished to the purchaser.

8. Product Analysis

8.1 An analysis of either one billet or one tube shall be made for each heat of steel. Samples for chemical analysis, except spectrochemical analysis, shall be taken in accordance with Method E59. The chemical composition thus determined shall conform to the requirements specified in Section 6.

8.2 If the original test for product analysis fails, retests of two additional billets or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of the specification, otherwise all remaining material in the heat or lot shall be

TABLE 4 Heat Treatment of Austenitic Stainless Steels

Grade	Temperature °F [°C]	Quench
N08020	1700–1850 [925–1010][A,B]	quenched in water or rapidly cooled by other means
N08367	2025 [1105][A]	quenched in water or rapidly cooled by other means
N08810	2050 [1120][A]	quenched in water or rapidly cooled by other means
N08811	2100 [1150][A]	quenched in water or rapidly cooled by other means
N08904	2000 [1100][A]	quenched in water or rapidly cooled by other means
N08925	2010–2100 [1100–1150][A]	quenched in water or rapidly cooled by other means
N08926	2010–2100 [1100–1150][A]	quenched in water or rapidly cooled by other means

[A]Quenched in water or rapidly cooled by other means, at a rate sufficient to prevent re-precipitation of carbides, as demonstrable by the capability of tubes, heat treated by either separate solution annealing or by direct quenching, passing Practices A262, Practice E. The manufacture is not required to run the test unless it is specified on the purchase order. Note that Practices A262 requires the test to be performed on sensitized specimens in the low-carbon and stabilized types and on specimens representative of the as-shipped condition for other types. In the case of low-carbon types containing 3 % or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and the purchaser.
[B]Material shall be supplied in stabilized annealed condition.

TABLE 45 Heat Treatment of Austenitic-Ferritic Stainless Steels

Grade	Temperature °F [°C]	Quench
S31260	1870-2010 [1020-1100]	rapid cooling in air or water
S31803	1870-2010 [1020-1100]	rapid cooling in air or water
S32101	1870 [1020] min	quenched in water or rapidly cooled by other means
S32205	1870-2010 [1020-1100]	rapid cooling in air or water
S32304	1700-1920 [925-1050]	rapid cooling in air or water
S32506	1870-2050 [1020-1120]	rapid cooling in air or water
S32550	1900 [1040] min	rapid cooling in air or water
S32707	1975-2050 [1080-1120]	rapid cooling in air or water
S32750	1880-2060 [1025-1125]	rapid cooling in air or water
S32760	1960-2085 [1070-1140]	rapid cooling in air or water
S32808	1920-2100 [1050-1150]	rapid cooling in air or water
S32906	1870-2100 [1020-1150]	rapid cooling in air or water
S32950	1820-1880 [990-1025]	air cool
S39274	1880-2060 [1025-1125]	rapid cooling in air or water

rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of this specification shall be rejected.

9. Permissible Variations in Dimensions of Round Tubing

9.1 *Diameter and Wall Thickness (Cold Finished)*—
Variations in outside diameter and wall thickness shall not exceed the amounts prescribed in Table 56.

9.2 *Diameter and Wall Thickness (Hot Finished)*—
Variations in outside diameter and wall thickness shall not exceed the amounts prescribed in Table 67.

9.3 *Lengths (Cold Finished or Hot Finished)*—Mechanical tubing is commonly furnished in mill lengths 5 ft [1.5 m] and over. When random lengths are ordered, tube lengths may vary by an amount up to 7 ft [2.1 m]. Definite cut lengths are furnished, when specified, to the length tolerances shown in Table 56 or Table 67. For tubing ordered in multiple lengths, it is common practice to allow a definite amount over for each multiple for the purchaser's cutting operations. This amount depends on the type of purchaser's cutting and varies with differing wall thickness. The cutting allowance should be specified on the purchase order. When it is not specified, tubing is customarily supplied with the following allowance for each multiple:

Wall Thickness, in. [mm]	Excess Length per Multiple, in. [mm]
Up to ⅛ [3.2]	⅛ [3]
Over ⅛ to ½ [3.2 to 12.7]	3⁄16 [5]
Over ½ [12.7]	¼ [6]

9.4 *Straightness Tolerances (Cold Finished or Hot Finished)*—The deviation from straightness shall not exceed the amounts shown in Table 78 when measured with a 3-ft [1-m] straightedge and feeler ~~gage.~~gauge. If determined by the dial indicator method, the values obtained will be approximately twice those determined by the straightedge feeler ~~gage~~gauge method.

10. Permissible Variations in Dimensions of Square and Rectangular Tubing

10.1 Square and rectangular seamless stainless mechanical tubing is supplied as cold worked unless otherwise specified. For this tubing, variations in dimensions from those specified shall not exceed the amounts prescribed in Table 89, Table 910, Table 1011, and Table 1112.

10.2 The squareness of sides is commonly determined by one of the following methods.

10.2.1 A square, with two adjustable contact points on each arm, is placed on two sides. A fixed feeler ~~gage~~gauge is then used to measure the maximum distance between the free contact point and the surface of the tubing.

10.2.2 A square, equipped with a direct reading vernier, may be used to determine the angular deviation which, in turn, may be related to distance in inches.

10.3 The squareness of sides varies in accordance with the following equation:

$$\pm\, b = c \times 0.006$$

where:

b = tolerance for out-of-square, and
c = length of longest side.

Example: Rectangular tubes 2 by 1 may have sides fail to be 90° to each other by ± 0.012 in. [0.3 mm].

10.4 The twist in square and rectangular tubing may be measured by holding one end of the tubing on a surface plate and noting the height above the surface plate of either corner of the opposite end of the same side. Twist may also be measured by the use of a beveled protractor, equipped with a level, and noting the angular deviation on opposite ends, or at any point throughout the length.