

Standard Specification for Seamless Stainless Steel Mechanical Tubing and Hollow Bar¹

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 or as hollow bar for use in the production of hollow components such as, but not limited to nozzles, reducers, and couplings by machining 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 hollow bar and seamless hot-finished mechanical tubing and hollow bar in sizes up to 12¾ in. [325 mm] in outside nominal diameter (for round tubing) with wall thicknesses or inside diameters as required.

1.3 Tubes for mechanical applications shall be furnished in one of the following shapes, as specified by the purchaser: round, square, rectangular, or special. Tubes to be used as hollow bar shall be furnished in round shape.

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 Standards:²

[A262 Practices for Detecting Susceptibility to Intergranular](#)

[Attack in Austenitic Stainless Steels](#)

[A1016/A1016M Specification for General Requirements for](#)

[Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes](#)

[A1058 Test Methods for Mechanical Testing of Steel Products—Metric](#)

[E112 Test Methods for Determining Average Grain Size](#)

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 Standard:

[Fed. Std. No. 123 Marking for Shipments \(Civil Agencies\)](#)³

3. Terminology

3.1 Definitions:

3.1.1 *hollow bar*—round tubing that is intended to produce engineering components by machining, generally specified by minimum outside diameter and maximum inside diameter.

3.1.2 *mechanical tubing*—tubing of various shapes used for mechanical and general engineering purposes, specified by nominal outside dimension and nominal wall.

4. Ordering Information

4.1 Orders for material under this specification should include the following as required to describe the desired material adequately:

4.1.1 Quantity (feet, mass, or number of pieces),

4.1.2 Name of material (seamless stainless steel mechanical tubing or hollow bar),

4.1.3 Mechanical Tubing Form only (round, square, rectangular, special, see [Section 1](#)),

4.1.4 Dimensions (round, nominal outside diameter and nominal wall thickness, (see [11.1](#) and [11.2](#)) or minimum outside diameter and maximum inside diameter (see [11.3](#)); square and rectangular, nominal outside dimensions and nominal wall thickness, see [Section 12](#); other, specify),

4.1.5 Length (specific or random, see [11.4](#)),

4.1.6 Manufacture (cold- or hot-finished, see [6.5](#)),

4.1.7 Grade ([Section 8](#)),

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

TABLE 1 Chemical Requirements of Austenitic Stainless Steels

Grade	Composition, %												
	Carbon	Manga- nese, max	Phos- pho- rus, max	Sul- fur, max	Silicon, max	Nickel	Chromium	Molybdenum	Titanium	Niobium ^D	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
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	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
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
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
N08925	0.020 max	1.00	0.045	0.030	0.50	24.0–26.0	19.0–21.0	6.0–7.0	...	...	...	...	Cu 1.00–2.00
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 0.10–0.20
													Cu 0.80–1.50
													N 0.15–0.25
													Cu 0.40–1.50

^AFor 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).

^BIron shall be determined arithmetically by difference of 100 minus the sum of the other specified elements.

^CThe range of (Al + Ti) shall be within 0.85–1.20 %.

^DThe terms Niobium (Nb) and Columblum (Cb) are alternate names for the same element.

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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	...

^AMT446-2 is a lower carbon version of MT446-1, that has a lower tensile strength but improved ductility and toughness.

^BCarbon 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	Other Elements
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

^AMaximum, 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.

4.1.8 Condition (annealed, as cold worked, or with special heat treatment, controlled microstructural characteristics, or other condition as required, see Section 7),

4.1.9 Surface finish (special pickling, shot blasting, or polishing, as required, see Supplementary Requirement S5),

4.1.10 Specification designation,

4.1.11 Report of Chemical Analysis, if required (Sections 9 and 10),

4.1.12 Individual supplementary requirements, if required,

NOTE 1—Supplementary requirements S1 and S2 are required for hollow bar only (see Section 13).

4.1.13 End use,

4.1.14 Packaging,

4.1.15 Special marking (see 18.2),

4.1.16 Special packing (see 19.2), and

4.1.17 Special requirements.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification **A1016/A1016M** unless otherwise provided herein.

6. Materials and Manufacture

6.1 The steel may be made by any process.

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

6.3 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.

6.4 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.

6.5 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.

7. Condition

7.1 Round seamless stainless mechanical tubing is generally supplied in the cold-worked and annealed condition (see 7.2 through 7.5). 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. Round seamless hollow bar is generally applied in the hot-worked and annealed condition.

7.2 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.

7.3 Unless otherwise specified, all austenitic mechanical tubing and hollow bar, except for UNS N08020 shall be furnished in the solution annealed condition. Unless otherwise specified in Table 4, the solution 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 mechanical tubing or hollow bar is not less than the specified minimum solution treatment temperature, tubes may be individually quenched in water or rapidly cooled by other means. This solution anneal shall precede final cold work, when cold-worked tempers are required. UNS N08020 shall be furnished in the stabilized annealed condition.

7.4 All austenitic-ferritic mechanical tubing and hollow bar shall be furnished in the solution annealed condition as prescribed in Table 5. Alternatively, immediately following hot forming, while the temperature of the mechanical tubing or hollow bar is not less than the specified minimum solution

treatment temperature, tubes may be individually quenched in water or rapidly cooled by other means.

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

8. Chemical Composition

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

9. Heat Analysis

9.1 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.

10. Product Analysis

10.1 An analysis of either one billet or one tube shall be made for each heat of steel. The chemical composition thus determined shall conform to the requirements specified in Section 8.

10.2 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 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.

11. Permissible Variations in Dimensions of Round Mechanical Tubing and Hollow Bar

11.1 *Nominal Outside Diameter and Nominal Wall Thickness (Cold Finished Mechanical Tubing and Hollow Bar)*—

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

^AQuenched 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.

^BMaterial shall be supplied in stabilized annealed condition.

TABLE 5 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

Variations in outside diameter and wall thickness shall not exceed the amounts prescribed in [Table 6](#).

11.2 *Nominal Diameter and Nominal Wall Thickness (Hot Finished Mechanical Tubing and Hollow Bar)*—

Variations in outside diameter and wall thickness shall not exceed the amounts prescribed in [Table 7](#).

11.3 *Minimum Outside Diameter and Maximum Inside Diameter (Cold-Finished and Hot-Finished Hollow Bar)*—

Variations in outside diameter and wall thickness shall not exceed the amounts prescribed in [Table 8](#).

11.4 *Lengths (Cold Finished or Hot Finished)*—Mechanical tubing and hollow bar are commonly furnished in mill lengths 5 ft [1.5 m] and over. When random lengths are ordered, mechanical tubing and hollow bar 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 6](#) or [Table 7](#). For mechanical tubing and hollow bar 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, mechanical tubing and hollow bar are customarily supplied with the following allowance for each multiple:

Wall Thickness, in. [mm]	Excess Length per Multiple, in. [mm]
Up to 1/8 [3.2]	1/8 [3]
Over 1/8 to 1/2 [3.2 to 12.7]	3/16 [5]
Over 1/2 [12.7]	1/4 [6]

11.5 *Straightness Tolerances (Cold Finished or Hot Finished Mechanical Tubing)*—The deviation from straightness shall not exceed the amounts shown in [Table 9](#) when measured with a 3-ft [1-m] straightedge and feeler gauge. If determined by the dial indicator method, the values obtained will be approximately twice those determined by the straightedge feeler gauge method.

11.6 *Straightness Tolerances (Cold Finished or Hot Finished Hollow Bar)*—The deviation from straightness of any hollow bar length (L) shall not exceed 0.0015 L, and not exceeding 0.072 in. per 3 ft [2 mm per 1 m] when measured with a 3-ft [1-m] straight edge and feeler gage. If determined

by the dial indicator method, the values obtained will be approximately twice those determined by the straight edge – feeler gage method.

12. Permissible Variations in Dimensions of Square and Rectangular Mechanical Tubing

12.1 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 10](#), [Table 11](#), [Table 12](#), and [Table 13](#).

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

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

12.2.2 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.

12.3 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].

12.4 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.

13. Mechanical Properties – Hollow Bar

13.1 Tensile Requirements:

13.1.1 The material shall conform to the requirements of the tensile properties given in [Table S2.1](#).

TABLE 6 Permissible Variations in Outside Diameter, Ovality, Wall Thickness, and Cut-Length Variations (Cold-Finished Round Mechanical Tubing and Hollow Bar)^A

Outside Nominal Diameter, in. [mm]	Prevailing Range of Commercially Available Metric Sizes, mm	Outside Diameter, ^B Tolerance, ^B in. [mm] Over and Under	Ovality, ^B Double Outside Diameter Tolerance when wall is:	Wall Thickness in % ^{C,D}		Permissible Variations in Cut Length, in. [mm] ^E
				Over	Under	
Under ½ [13]	Under 12.7	0.005 [0.1]	less than 0.015 in. [0.4 mm]	15	15	½ [3]
½ [13] to 1½ [38], excl	12.7 to 38.1, excl	0.005 [0.1]	less than 0.065 in. [1.6 mm]	10	10	½ [3]
1½ [38] to 3½ [90], excl	38.1 to 88.9 excl	0.010 [0.3]	less than 0.095 in. [2.4 mm]	10	10	¾ [5]
3½ [90] to 5½ [140], excl	88.9 to 139.7, excl	0.015 [0.4]	less than 0.150 in. [3.8 mm]	10	10	¾ [5]
5½ [140] to 8 [200], excl	139.7 to 203.2, excl	0.030 [0.8]	less than 0.240 in. [6.1 mm]	10	10	¾ [5]
8 [200] to 8½ [220], excl	203.2 to 219.1, excl	0.045 [1.1]	less than 0.300 in. [7.6 mm]	10	10	¾ [5]
8½ [220] to 12¾ [325], incl	219.1 to 323.9, incl	0.062 [1.6]	less than 0.350 in. [8.9 mm]	10	10	¾ [5]

^ATolerances of tubes produced by the rod or bar mandrel process and which have an inside diameter under ½ in. [12.7 mm] (or an inside diameter under ⅝ in. [15.8 mm] when the wall thickness is more than 20 % of the outside diameter) are as shown in this table, except that wall thickness tolerances are 10 % over and under the specified wall thickness.

^BFor ovality values, the tolerance for average outside diameter at any one cross section does not exceed the outside diameter tolerance value for the applicable outside diameter.

^CMany tubes with wall thicknesses more than 25 % of outside diameter or with wall thicknesses over 1¼ in., [31.7 mm] or weighing more than 90 lb/ft [60.5 kg/m], are difficult to draw over a mandrel. Therefore, the wall thickness can vary 12½ % over and under that specified. Also see Footnote (B).

^DFor those tubes with inside diameter under ½ in. [12.7 mm] (or under ⅝ in. [15.8 mm] when the wall thickness is more than 20 % of the outside diameter) which are not commonly drawn over a mandrel, Footnote (A) is not applicable. Therefore, the wall thickness can vary 15 % over and under that specified, and the inside diameter is governed by both the outside diameter and wall thickness tolerances.

^EThese tolerances apply to cut lengths up to and including 24 ft. [7.3 m]. For lengths over 24 ft [7.3 m], an additional over tolerance of ⅛ in. [3 mm] for each 10 ft [3 m] or fraction thereof shall be permissible, up to a maximum tolerance of ½ in. [13 mm].

**TABLE 7 Permissible Variations in Outside Diameter, Wall Thickness, and Cut-Length Variations
(Hot-Finished Round Mechanical Tubing and Hollow Bar)**

Specified Nominal Inch Size, Outside Diameter, in. [mm]	Prevailing Range of Commercially Available Metric Sizes, mm	Ratio of Wall Thickness to Outside Diameter	Outside Diameter and Wall Thickness Tolerances												Permissible Variations in Cut Length, in. [mm] ⁴
			Outside Diameter, in. [mm]				Wall Thickness, %								
			0.109 in. [2.77 mm] and under		0.109 [2.77] to 0.172 in. [4.37 mm], incl		0.172 [4.37] to 0.203 in. [5.16 mm], incl		Over 0.172 [4.37] to 0.203 in. [5.16 mm], incl		Over 0.203 in. [5.16 mm]				
			Over	Under	Over	Under	Over	Under	Over	Under	Over	Under			
			Over	Under	Over	Under	Over	Under	Over	Under	Over	Under			
Under 3 [75]	Under 76.1	all wall thicknesses	0.023 [0.6]	0.023 [0.6]	16.5	16.5	15	15	14	14	12.5	12.5	3/16 [4.8]	0	
3 [75] to 5 1/2 [140], excl	76.1 to 139.7, excl	all wall thicknesses	0.031 [0.8]	0.031 [0.8]	16.5	16.5	15	15	14	14	12.5	12.5	3/16 [4.8]	0	
5 1/2 [140] to 8 [200], excl	139.7 to 203.2, excl	all wall thicknesses	0.047 [1.2]	0.047 [1.2]	...	...	...	...	14	14	12.5	12.5	3/16 [4.8]	0
8 [200] to 10 3/4 [275], excl	203.2 to 273.1, excl	5% and over	0.047 [1.2]	0.047 [1.2]	...	...	...	...	...	...	12.5	12.5	3/16 [4.8]	0
10 3/4 [275] to 12 3/4 [325], incl	273.1 to 323.9, incl	under 5 %	0.063 [1.6]	0.063 [1.6]	...	...	...	...	...	...	12.5	12.5	3/16 [4.8]	0

⁴These tolerances apply to cut lengths up to and including 24 ft [7.3 m]. For lengths over 24 ft [7.3 m], an additional over tolerance of 1/8 in. [3 mm] for each 10 ft [3 m] or fraction thereof shall be permissible, up to a maximum tolerance of 1/2 in. [13 mm].

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TABLE 8 Permissible Variations in Minimum Outside Diameter and Maximum Inside Diameter (Cold-Finished and Hot-Finished Round Hollow Bar)

Minimum Outside Diameter (D) in. [mm]	Tolerance on Outside Diameter in. [mm]		Maximum Inside Diameter (d) in. [mm]	Tolerance on Inside Diameter in. [mm]	
	Over	Under		Over	Under
D < 2 [50]	0.04 [1]	0.00 [0]	d < 2 [50]	0.00 [0]	0.04 [1]
D ≥ 2 [50]	0.02 D ^A	0.00 [0]	d < 2 [50]	0.00 [0]	0.04 [1]
D ≥ 2 [50]	0.02 D ^A	0.00 [0]	d ≥ 2 [50]	0.00 [0]	0.02 d ^B

^ACalculate value: 2 % × Specified Minimum Outside Diameter.

^BCalculate value: 2 % × Specified Maximum Inside Diameter.

TABLE 9 Straightness Tolerances (Cold-Finished or Hot-Finished Round Mechanical Tubing)^A

Nominal Inch Size Limits	Max Curvature in any 3 ft [1 m], in. [mm]	Max Curvature in Total Lengths, in. [mm]	Max Curvature for Lengths under 3 ft [1 m]
OD 5 in. [125 mm] and smaller. Wall thickness, over 3 % of OD but not over 0.5 in. [12.7 mm]	0.030 [1]	0.030 × [(Number of feet of length)/3] [1 × Number of metres]	Ratio of 0.010 in./ft [Ratio of 1 mm/m]
OD over 5 in. [125 mm] to 8 in. [200 mm], incl. Wall thickness, over 4 % of OD but not over 0.75 in. [19 mm]	0.045 [1]	0.045 × [(Number of feet of length)/3] [1 × Number of metres]	Ratio of 0.015 in./ft [Ratio of 1 mm/m]
OD over 8 in. [200 mm] to 12¾ in. [325 mm], incl. Wall thickness, over 4 % of OD but not over 1 in. [25 mm]	0.060 [2]	0.060 × [(Number of feet of length)/3] [2 × Number of metres]	Ratio of 0.020 in./ft [Ratio of 2 mm/m]

^AThe usual procedure for measuring straightness is by means of a 3-ft [1 m] straight edge and feeler gauge. If determined by the dial indicator method, the values obtained will be approximately twice those determined by the straightedge feeler gauge method.

TABLE 10 Permissible Variations in Outside Dimensions for Square and Rectangular Seamless Mechanical Tubing^{AB}

Largest Nominal Outside Dimension Across Flats, in. [mm]	Tolerances, Outside Dimension Seamless Mechanical Tubing Plus and Minus, in. [mm]	
	For Wall Thickness, Given, in. [mm]	Tolerance for Outside Dimension (Including Convexity or Concavity) Plus and Minus, in. [mm]
To ¾ [20], incl	0.065 [1.6] and lighter	0.015 [0.4]
To ¾ [20], incl	over 0.065 [1.6]	0.010 [0.3]
Over ¾ [20] to 1 [25], incl	all thicknesses	0.015 [0.4]
Over 1¼ [30] to 2½ [65], incl	all thicknesses	0.020 [0.6]
Over 2½ [65] to 3½ [90], incl	0.065 [1.6] and lighter	0.030 [0.8]
Over 2½ [65] to 3½ [90], incl	over 0.065 [1.6]	0.025 [0.6]
Over 3½ [90] to 5½ [140], incl	all thicknesses	0.030 [0.8]
Over 5½ [140] to 7½ [190], incl	all thicknesses	1 %

^AThe wall thickness tolerance is plus and minus 10 % of nominal wall thickness.

^BThe straightness tolerance is 0.075 in. 3 ft. [2 mm/m] using a 3-ft [1 m] straight edge and feeler gauge.

TABLE 11 Permissible Variations in Radii of Corners for Square and Rectangular Seamless Mechanical Tubing

Wall Thickness, in. [mm]	Maximum Radii of Corners, in. [mm]
Over 0.020 to 0.049 [0.5 to 1.0], incl	⅜ [2.4]
Over 0.049 to 0.065 [1.0 to 1.6], incl	⅙ [3.2]
Over 0.065 to 0.083 [1.6 to 2.1], incl	⅝ [3.6]
Over 0.083 to 0.095 [2.1 to 2.4], incl	⅜ [4.8]
Over 0.095 to 0.109 [2.4 to 2.8], incl	1⅜ [5.2]
Over 0.109 to 0.134 [2.8 to 3.4], incl	7/32 [5.6]
Over 0.134 to 0.156 [3.4 to 4.0], incl	¼ [6.4]
Over 0.156 to 0.188 [4.0 to 4.8], incl	9/32 [7.1]
Over 0.188 to 0.250 [4.8 to 6.4], incl	11/32 [8.7]
Over 0.250 to 0.313 [6.4 to 8.0], incl	7/16 [11.1]
Over 0.313 to 0.375 [8.0 to 9.5], incl	½ [12.7]
Over 0.375 to 0.500 [9.5 to 12.7], incl	11/16 [17.5]
Over 0.500 to 0.625 [12.7 to 15.9], incl	27/32 [21.4]

TABLE 12 Twist Tolerances for Square and Rectangular Mechanical Tubing

Largest Nominal Size, in. [mm]	Maximum Twist in 3 ft [1.0 m], in. [mm]
Under ½ [15]	0.050 [1.4]
½ [15] to 1½ [40], incl	0.075 [2.1]
Over 1½ [40] to 2½ [65], incl	0.095 [2.7]
Over 2½ [65]	0.125 [3.5]

13.1.2 One tension test shall be made on a specimen from one tube for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes. See 13.3.

13.2 Hardness Requirements:

13.2.1 The material shall conform to the hardness requirements given in Table S1.1.

13.2.2 Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot. See 13.3.

13.3 The term lot applies to all tubes prior to cutting, of the same size that are produced from the same heat of steel. When

final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, or when the heat-treated condition is obtained directly by quenching after hot forming, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed; or all tubes of the same size and heat, hot formed and quenched in the same production run.

TABLE 13 Length Tolerances for Square and Rectangular Mechanical Tubing

Length tolerance on exact lengths of tubing (all types), in. [mm]	+3/8, - 0
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NOTE 2—The mechanical properties in Section 13 are required for hollow bar only. To be applicable to mechanical tubing, the appropriate supplementary requirements must be cited per 4.1.12.

14. Workmanship, Finish, and Appearance

14.1 Finished tubes shall have smooth ends free of burrs. They shall be free of injurious defects and shall have a workmanlike finish. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits and scale pattern, will not be considered as injurious defects, provided the imperfections are removable within the wall tolerance unless a machining allowance has been specified. When a machining allowance has been specified, the imperfections shall be removable within the machining allowances. The removal of surface imperfections is not required.

14.2 Tubes shall be free of scale and suitable for inspection.

15. Machining Allowances of Hollow Bar

15.1 Clean-up or machining allowances for stainless steel hollow bar are shown in Table 14. For the method of

TABLE 14 Cleanup or Machining Allowances for Hollow Bar^A

For Machined Parts, Nominal Size, Outside Diameter, in. [mm]	Machining Allowances on Diameter, in. [mm]	
	Outside Diameter	Inside Diameter
Less than 3/32 [2.4]	0.008 [0.2]	0.008 [0.2]
3/32 [2.4] to 3/16 [4.8], excl	0.012 [0.3]	0.012 [0.3]
3/16 [4.8] to 1/2 [13], excl	0.015 [0.4]	0.015 [0.4]
1/2 [13] to 1 1/2 [40], excl	0.020 [0.5]	0.020 [0.5]
1 1/2 [40] to 3 [75], excl	0.040 [1.0]	0.040 [1.0]
3 [75] to 5 1/2 [140], excl	0.060 [1.5]	0.060 [1.5]
5 1/2 [140] to 8 [200], ^B excl	0.080 [2.0]	0.080 [2.0]

^AThe allowances in this table are nominal allowances which have been satisfactorily used for many applications but are not necessarily adequate for all tubular products and methods of machining. For example, when magnetic particle inspection or aircraft quality requirements are involved, it is customary to use greater allowances than those shown in the foregoing table.

^BFor machining allowances for sizes 8 in. [200 mm] and over the producer should be consulted.

calculating the hollow bar size required to clean up in machining to a particular finished part, see Appendix X1.

16. Rejection

16.1 Tubing that fails to meet the requirements of this specification shall be set aside and the manufacturer notified.

17. Coating

17.1 Stainless tubing is commonly shipped without protective coating. If special protection is needed, details shall be shown on the order.

18. Product and Package Marking

18.1 *Civilian Procurement*—Each box, bundle, lift, or piece shall be identified by a tag or stencil with the manufacturer's name or brand, specified size (nominal OD × nominal wall or minimum outside diameter × maximum inside diameter), purchaser's order number, grade, and this specification number.

18.2 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the Government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for Military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

19. Packaging

19.1 *Civilian Procurement*—On tubing 0.065 in. [1.6 mm] wall and under, the manufacturer will, at his option, box, crate, carton, package in secure lifts, or bundle to ensure safe delivery. Tubing over 0.065 in. [1.6 mm] wall will normally be shipped loose, bundled, or in secured lifts. Special packaging requiring extra operations other than those normally used by the manufacturer must be specified on the order.

19.2 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the Government when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

20. Keywords

20.1 austenitic stainless steel; duplex stainless steel; ferritic/austenitic stainless steel; hollow bar; mechanical tubing; seamless steel tube; stainless steel tube; steel tube

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order and the necessary tests shall be made at the mill. In the case of hollow bar, S1 Hardness Test and S2 Tension Test are required by this specification.

S1. Hardness Test

S1.1 The tubes shall conform to the hardness limits specified in **Table S1.1**, unless cold worked tempers or special thermal treatments are ordered, in which case the manufacturer should be consulted for expected hardness values.

S1.2 When specified, the hardness test shall be performed on a specimen from one tube from each lot of 100 tubes or fraction thereof from each heat of steel.

S2. Tension Test

S2.1 Unless cold-worked tempers or special thermal treatments are ordered, the tubes shall conform to the tensile requirements shown in **Table S2.1**. When cold-worked tempers or special thermal treatments are ordered, the tube manufacturer should be consulted.

S2.2 When the tension test is specified, one test shall be performed on a specimen from one tube taken from each lot of 100 tubes or fraction thereof from each heat of steel.

S2.3 The yield strength corresponding to a permanent offset of 0.2 % of the gauge length of the specimen or to a total extension of 0.5 % of the gauge length under load shall be determined.

TABLE S1.1 Hardness Requirements for Round Tubing in Annealed Condition^A

Grade	Brinell Hardness Number, HBW, max	Rockwell Hardness Number, max
All austenitic	192	90 ^B
MT 403	207	95 ^B
MT 405	207	95 ^B
MT 410	207	95 ^B
MT 414	235	99 ^B
MT 416 Se	230	97 ^B
MT 429/MT 430	190	90 ^B
MT 431	260	...
MT 440 A	215	95 ^B
MT 443	207	95 ^B
MT 446	207	95 ^B
29-4	207	95 ^B
29-4-2	207	95 ^B
S31260	...	...
S31803	290	30 ^C
S32101	290	...
S32205	290	30 ^C
S32304	290	30 ^C
S32506	302	32 ^C
S32550	297	31 ^C
S32707	318	34 ^C
S32750	300	32 ^C
S32760	300	...
S32808	310	32 ^C
S32906	300	32 ^C
S32950	290	30 ^C
S39274	310	32 ^C
N08020	217	...
N08367	...	...
>3/16 in. [4.8 mm] wall	241	...
N08925	217	...
N08926	256	...

^ANot applicable when cold-worked tempers or special thermal treatment is ordered. Where ellipses (...) appear in this table, there is no requirement.

^BHRB Scale.

^CHRC Scale.

TABLE S2.1 Tensile Requirements for Round Tubing in Annealed Condition^A

Grade	Tensile Strength, min, ksi [MPa]	Yield Strength min, ksi [MPa]	Elongation ^B in 2 in., or [50 mm] min., %
All austenitic steels ^C	75 [515]	30 [210]	35
MT 403	60 [415]	30 [210]	20
MT 405	60 [415]	30 [210]	20
MT 410	60 [415]	30 [210]	20
MT 414	100 [690]	65 [450]	15
MT 416 Se	60 [415]	35 [240]	20
MT 429/MT 430	60 [415]	35 [240]	20
MT 431	105 [725]	90 [620]	20
MT 440 A	95 [655]	55 [380]	15
MT 443	70 [485]	40 [275]	20
MT 446-1	70 [485]	40 [275]	18
MT 446-2	65 [450]	40 [275]	20
29-4	70 [485]	55 [380]	20
29-4-2	70 [485]	55 [380]	20
S31260	100 [690]	65 [450]	25
S31803	90 [620]	65 [450]	25
S32101	...	...	...
Wall ≤ 0.187 in. [5.00 mm]	101 [700]	77 [530]	30
Wall > 0.187 in. [5.00 mm]	94 [650]	65 [450]	30
S32205	95 [655]	70 [485]	25
S32304	...	...	...
OD 1 in. [25 mm] and Under	100 [690]	65 [450]	25
OD Over 1 in. [25 mm]	87 [600]	58 [400]	25
S32506	90 [620]	65 [450]	18
S32550	110 [760]	80 [550]	15
S32707	133 [920]	101 [700]	25
S32750	116 [800]	80 [550]	15
S32760	109 [750]	80 [550]	25
S32808	116 [800]	80 [550]	15
S32906	...	...	...
Wall below 0.40 in. [10 mm]	116 [800]	94 [650]	25
Wall 0.40 in. [10 mm] and above	109 [750]	80 [550]	25
S32950	100 [690]	70 [480]	20
S39274	116 [800]	80 [550]	15
N08020	80 [550]	35 [240]	30
N08367	...	...	...
≤3/16 in. [4.8 mm] wall	100 [690]	45 [310]	30
>3/16 in. [4.8 mm] wall	95 [655]	45 [310]	30
N08800	...	...	...
cold worked annealed	75 [515]	30 [205]	30
hot-finished annealed	65 [450]	25 [170]	30
N08810	65 [450]	25 [170]	30
N08811	65 [450]	25 [170]	30
N08904	71 [490]	31 [215]	35
N08925	87 [600]	43 [295]	40
N08926	94 [650]	43 [295]	35

^ANot applicable to tubes under a 1/8 in. [3.1 mm] outside diameter or less than 0.015 in. [0.4 mm] in wall thickness, or both. The tensile properties of such small diameter or thin wall tubes are a matter of agreement between manufacturer and purchaser. For tubing having an outside diameter of 3/8 in. [9.5 mm] or under, the gauge length shall be four times the outside diameter in order to obtain elongation values comparable to the larger sizes (Test Method A1058).

^BFor longitudinal strip tests, the width of the gauge section shall be 1 in. [25 mm]. A deduction of 1.0 percentage points for ferritic and martensitic grades shall be permitted from the basic minimum elongation for each 1/32 in. [0.8 mm] decrease in wall thickness under 5/16 in. [7.9 mm]. The calculated elongation requirement shall be rounded to the nearest whole number.

^CWhen grades TP304L, and TP316L are required to pass special corrosion tests, these minimum values for tensile strength and yield strength may not be met.

S3. Nondestructive Tests

S3.1 Various types of nondestructive ultrasonic or electromagnetic tests are available. When any such test is required, the test to be used and the inspection limits required shall be specified. Generally, for ultrasonic test, the most restrictive

limit which may be specified is 3 % of the wall thickness or 0.004 in. [0.10 mm] (whichever is greater). For a description and inspection table of another type of non-destructive electric test, see the section on Nondestructive Electric Test in Specification [A1016/A1016M](#).

S4. Hardenability

S4.1 Any requirement for special hardenability tests and test limits for martensitic stainless grades shall be detailed on the order. Hardenability requirements are not applicable to austenitic, austenitic-ferritic, or ferritic grades.

S5. Surface Finish

S5.1 Any special pickling, shotblasting, or polishing requirements shall be detailed in the order.

S6. Grain Size for Austenitic Grades

S6.1 All austenitic grades shall be tested for average grain size by Test Methods [E112](#).

S7. Certification for Government Orders

S7.1 A producer's or supplier's certification shall be furnished to the Government that the material was manufactured, sampled, tested, and inspected in accordance with this speci-

fication and has been found to meet the requirements. This certificate shall include a report of heat analysis (product analysis when requested in the purchase order), and when specified in the purchase order or contract, a report of test results shall be furnished.

S8. Rejection Provisions for Government Orders

S8.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the tube may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

S8.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such materials shall be a matter for agreement.

APPENDIX

(Nonmandatory Information)

X1. MACHINING ALLOWANCES FOR ROUND STAINLESS STEEL SEAMLESS TUBING

X1.1 Seamless tubing is produced either hot finished or cold worked. Hot finished tubes are specified to nominal outside diameter and nominal wall thickness or minimum outside diameter and maximum inside diameter. Cold-worked tubing is specified as follows: nominal outside diameter, nominal wall thickness, or minimum outside diameter and maximum inside diameter.

X1.2 There are two basic methods employed in machining such tubing: (1) by machining true to the outside diameter of the tube and (2) by machining true to the inside diameter of the tube.

X1.3 For the purpose of determining tube size dimensions with sufficient allowances for machining, the following four steps are customarily used.

X1.4 Step 1—Step 1 is used to determine the maximum tube outside diameter.

X1.4.1 *Machined Outside Diameter*—Purchaser's maximum blueprint (finish-machine) size including plus machine tolerance.

X1.4.2 *Cleanup Allowance*—Sufficient allowance should be made to remove surface imperfections.

X1.4.3 *Decarburization*—Decarburization is not important in most stainless grades but is an important factor on the higher

carbon grades or steel including Type 440A. Decarburization limits are shown in various specifications. For example, the decarburization limits for aircraft steels are shown in AMS and appropriate government specifications. Decarburization is generally expressed as depth and, therefore must be doubled to provide for removal from the surface.

X1.4.4 *Camber*—When the machined dimension extends more than 3 in. [75 mm] from the chuck or other holding mechanism, the possibility that the tube will be out-of-straight must be taken into consideration. An allowance is made equal to four times the straightness tolerance shown in [Table 9](#) or [11.6](#), for the machined length when chucked at only one end and equal to twice the straightness tolerance if supported at both ends.

X1.4.5 *Outside Diameter Tolerance*—If machined true to the outside diameter, add the complete spread of tolerance (for example, for specified outside diameter of 3 to 5½ in. [75 to 140 mm], exclusive, plus and minus 0.031 in. or 0.062 in. [0.8 mm or 1.6 mm]). If machined true to the inside diameter, outside diameter tolerances are not used in this step. Cold-worked tolerances are shown in [Table 6](#) or [Table 8](#). Hot-finished tolerances are shown in [Table 7](#) or [Table 8](#). The calculated maximum outside diameter is obtained by adding [X1.4.1](#) through [X1.4.5](#).



X1.5 Step 2—Step 2 is used to determine the minimum inside diameter.

X1.5.1 *Machined Inside Diameter*—Purchaser's minimum blueprint (finished-machine) size including machining tolerance.

X1.5.2 *Cleanup Allowance*—Sufficient allowance should be made to remove surface imperfections.

X1.5.3 *Decarburization*—Decarburization is an important factor on the higher carbon grades of steel including Type 440A. Decarburization limits are shown in various specifications. For example, the decarburization limits for aircraft are shown in AMS and appropriate government specifications. Decarburization is generally expressed as depth and therefore must be doubled to provide for removal from the surface.

X1.5.4 *Camber*—Refer to X1.4.4.

X1.5.5 *Inside Diameter Tolerances*—If machined true to the outside diameter, inside diameter tolerances are not used in this step. If machined true to the inside diameter, subtract the complete spread of tolerance (plus and minus). Cold-worked tolerances are shown in Table 7 or Table 8. Hot-finished tolerances (use outside diameter tolerances for inside diameter for calculating purposes) are shown in Table 6 and Table 8. The calculated minimum is obtained by subtracting the sum of X1.5.2 through X1.5.5 from X1.5.1.

X1.6 Step 3—Step 3 is used to determine the average wall thickness.

X1.6.1 One half the difference between the maximum outside diameter and the minimum inside diameter is considered to be the calculated minimum wall. From the calculated minimum wall, the average is obtained by dividing by 0.90 for cold-worked tubing or 0.875 for hot-finished tubing. This represents the wall tolerance of plus and minus 10 % for

cold-worked tubing and plus and minus 12½ % for hot-finished tubing. The wall tolerances may be modified in special cases as covered by applicable tables.

X1.7 Step 4—Step 4 is used to determine cold-worked or hot-finished tube size when machined true to the outside diameter or machined true to the inside diameter.

X1.7.1 *Cold Worked Machined True to Outside Diameter*—Size obtained in Step 1 minus the over tolerance (shown in “Over” column in Table 3 or Table 8) gives the outside diameter to be specified. The wall thickness to be specified is that determined in Step 3.

X1.7.2 *Cold Worked Machined True to Inside Diameter*—Size obtained in Step 2 plus twice the calculated wall obtained in Step 3 gives the minimum outside diameter. To find the outside diameter to be specified, add the under part of the tolerance shown in the under outside diameter column in Table 3 or Table 8. The average wall thickness to be specified is that determined in Step 3. If necessary to specify to inside diameter and wall, the under tolerance for inside diameter (shown in Table 3 or Table 8) is added to the inside diameter obtained in Step 2.

X1.7.3 *Hot Finished Machined True to Outside Diameter*—From the size obtained in Step 1, subtract one-half the total tolerance (shown in Table 6 or Table 8) to find the outside diameter to be specified. The average wall thickness to be specified is that determined in Step 3.

X1.7.4 *Hot Finished Machined True to Inside Diameter*—The average outside diameter to be specified is obtained by adding the under part of the tolerance (shown in the under column of Table 6 or Table 8) to the minimum outside diameter, calculated by adding twice the average wall (from Step 3) to the minimum inside diameter (from Step 2).

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A511/A511M–15a, that may impact the use of this specification. (Approved May 1, 2016)

(1) Added hollow bar as a product form.

(2) Added E112 to referenced documents and deleted references to A370 and E59.

(3) Added Supplementary Requirement for Grain Size for Austenitic Grades.

(4) Added Footnote D to Table 1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A511/A511M–15, that may impact the use of this specification. (Approved May 1, 2015)

(1) Revise the wall thickness values for applicable changes in tensile requirements for UNS S32906 in Table S2.1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A511/A511M–12, that may impact the use of this specification. (Approved January 1, 2015)

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(1) Added N08020, N08367, N08800, N08810, N08811, N08904, N08925, and N08926 to **Table 1**, **Table S1.1**, and **Table S2.1**

(2) Added new **Table 4** and renumbered subsequent tables. Added reference to **Table 4** in **7.3**.

(3) Deleted original Footnotes B and C and added requirements to **Table 1**.

(4) Added new Footnotes B and C to **Table 1**.

(5) Deleted reference to Ta in **Table 1** column heading.