**Designation: A 519 – 03**

# 机械用无缝碳钢管、合金钢管的标准规范
# Standard Specification for Seamless Carbon and Alloy Steel Mechanical Tubing[1]

This standard is issued under the fixed designation A 519; 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 Department of Defense. This standard replaces QQ-T-00825 and QQ-T-830.*

## 1. Scope*

1.1 This specification covers several grades of carbon and alloy steel seamless mechanical tubing. The grades are listed in Tables 1-3. When welding is used for joining the weldable mechanical tube grades, the welding procedure shall be suitable for the grade, the condition of the components, and the intended service.

1.2 This specification covers both seamless hot-finished mechanical tubing and seamless cold-finished mechanical tubing in sizes up to and including 12 ¾ in. (323.8 mm) outside diameter for round tubes with wall thicknesses as required.

1.3 The tubes shall be furnished in the following shapes, as specified by the purchaser: round, square, rectangular, and special sections.

1.4 Supplementary requirements of an optional nature are provided and when desired shall be so stated in the order.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

## 2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[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 Shipment (Civil Agencies)[4]

**TABLE 1 Chemical Requirements of Low-Carbon Steels**

| Grade Designation | Chemical Composition Limits, % | | | |
|---|---|---|---|---|
| | Carbon[A] | Manganese[B] | Phosphorus,[B] max | Sulfur,[B] max |
| MT 1010 | 0.05–0.15 | 0.30–0.60 | 0.040 | 0.050 |
| MT 1015 | 0.10–0.20 | 0.30–0.60 | 0.040 | 0.050 |
| MT X 1015 | 0.10–0.20 | 0.60–0.90 | 0.040 | 0.050 |
| MT 1020 | 0.15–0.25 | 0.30–0.60 | 0.040 | 0.050 |
| MT X 1020 | 0.15–0.25 | 0.70–1.00 | 0.040 | 0.050 |

[A] Limits apply to heat and product analyses.
[B] Limits apply to heat analysis; except as required by 6.1, product analyses are subject to the applicable additional tolerances given in Table 5.

## 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, weight, or number of pieces),

**TABLE 2 Chemical Requirements of Other Carbon Steels**

| Grade Designation | Chemical Composition Limits, %[A] | | | |
|---|---|---|---|---|
| | Carbon | Manganese | Phosphorus, max | Sulfur, max |
| 1008 | 0.10 max | 0.30–0.50 | 0.040 | 0.050 |
| 1010 | 0.08–0.13 | 0.30–0.60 | 0.040 | 0.050 |
| 1012 | 0.10–0.15 | 0.30–0.60 | 0.040 | 0.050 |
| 1015 | 0.13–0.18 | 0.30–0.60 | 0.040 | 0.050 |
| 1016 | 0.13–0.18 | 0.60–0.90 | 0.040 | 0.050 |
| 1017 | 0.15–0.20 | 0.30–0.60 | 0.040 | 0.050 |
| 1018 | 0.15–0.20 | 0.60–0.90 | 0.040 | 0.050 |
| 1019 | 0.15–0.20 | 0.70–1.00 | 0.040 | 0.050 |
| 1020 | 0.18–0.23 | 0.30–0.60 | 0.040 | 0.050 |
| 1021 | 0.18–0.23 | 0.60–0.90 | 0.040 | 0.050 |
| 1022 | 0.18–0.23 | 0.70–1.00 | 0.040 | 0.050 |
| 1025 | 0.22–0.28 | 0.30–0.60 | 0.040 | 0.050 |
| 1026 | 0.22–0.28 | 0.60–0.90 | 0.040 | 0.050 |
| 1030 | 0.28–0.34 | 0.60–0.90 | 0.040 | 0.050 |
| 1035 | 0.32–0.38 | 0.60–0.90 | 0.040 | 0.050 |
| 1040 | 0.37–0.44 | 0.60–0.90 | 0.040 | 0.050 |
| 1045 | 0.43–0.50 | 0.60–0.90 | 0.040 | 0.050 |
| 1050 | 0.48–0.55 | 0.60–0.90 | 0.040 | 0.050 |
| 1518 | 0.15–0.21 | 1.10–1.40 | 0.040 | 0.050 |
| 1524 | 0.19–0.25 | 1.35–1.65 | 0.040 | 0.050 |
| 1541 | 0.36–0.44 | 1.35–1.65 | 0.040 | 0.050 |

[A] The ranges and limits given in this table apply to heat analysis; except as required by 6.1, product analyses are subject to the applicable additional tolerances given in Table Number 5.

[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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[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] Withdrawn.

[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.**

3.1.2 Name of material (seamless carbon or alloy steel mechanical tubing),

3.1.3 Form (round, square, rectangular or special shapes, Section 1),

3.1.4 Dimensions (round, outside diameters and wall thickness, Section 8; square and rectangular, outside dimensions and wall thickness, Section 9; other, specify),

3.1.5 Length (specific or random, mill lengths, see 8.5 and 9.5),

3.1.6 Manufacture (hot finished or cold finished, 4.5 and 4.6),

3.1.7 Grade (Section 5),

3.1.8 Condition (sizing method and thermal treatment, Section 12),

3.1.9 Surface finish (special pickling, shot blasting, or ground outside surface, if required),

3.1.10 Specification designation,

3.1.11 Individual supplementary requirements, if required,

3.1.12 End use, if known,

3.1.13 Packaging,

3.1.14 Product analysis and chemical analysis, if required (Section 6 and Section 7),

3.1.15 Specific requirements, or exceptions to this specification,

3.1.16 Special marking (Section 15), and

3.1.17 Special packing (Section 16).

**TABLE 3 Chemical Requirements for Alloy Steels**

NOTE 1—The ranges and limits in this table apply to steel not exceeding 200 in.$^2$(1290 cm$^2$) in cross-sectional area.

NOTE 2—Small quantities of certain elements are present in alloy steels which are not specified or required. These elements are considered as incidental and may be present to the following maximum amounts: copper, 0.35 %; nickel, 0.25 %; chromium, 0.20 %; molybdenum, 0.10 %.

NOTE 3—The ranges and limits given in this table apply to heat analysis; except as required by 6.1, product analyses are subject to the applicable additional tolerances given in Table Number 5.

| Grade[A,B] Designation | Chemical Composition Limits, % | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Carbon | Manganese | Phosphorus,[C] max | Sulfur,[C,D] max | Silicon | Nickel | Chromium | Molybdenum |
| 1330 | 0.28–0.33 | 1.60–1.90 | 0.040 | 0.040 | 0.15–0.35 | ... | ... | ... |
| 1335 | 0.33–0.38 | 1.60–1.90 | 0.040 | 0.040 | 0.15–0.35 | ... | ... | ... |
| 1340 | 0.38–0.43 | 1.60–1.90 | 0.040 | 0.040 | 0.15–0.35 | ... | ... | ... |
| 1345 | 0.43–0.48 | 1.60–1.90 | 0.040 | 0.040 | 0.15–0.35 | ... | ... | ... |
| 3140 | 0.38–0.43 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | 1.10–1.40 | 0.55–0.75 | ... |
| E3310 | 0.08–0.13 | 0.45–0.60 | 0.025 | 0.025 | 0.15–0.35 | 3.25–3.75 | 1.40–1.75 | ... |
| 4012 | 0.09–0.14 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | ... | 0.15–0.25 |
| 4023 | 0.20–0.25 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | ... | 0.20–0.30 |
| 4024 | 0.20–0.25 | 0.70–0.90 | 0.040 | 0.035−0.050 | 0.15–0.35 | ... | ... | 0.20–0.30 |
| 4027 | 0.25–0.30 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | ... | 0.20–0.30 |
| 4028 | 0.25–0.30 | 0.70–0.90 | 0.040 | 0.035−0.050 | 0.15–0.35 | ... | ... | 0.20–0.30 |
| 4037 | 0.35–0.40 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | ... | 0.20–0.30 |
| 4042 | 0.40–0.45 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | ... | 0.20–0.30 |
| 4047 | 0.45–0.50 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | ... | 0.20–0.30 |
| 4063 | 0.60–0.67 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | ... | 0.20–0.30 |
| 4118 | 0.18–0.23 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.40–0.60 | 0.08–0.15 |
| 4130 | 0.28–0.33 | 0.40–0.60 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.80–1.10 | 0.15–0.25 |
| 4135 | 0.33–0.38 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.80–1.10 | 0.15–0.25 |
| 4137 | 0.35–0.40 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.80–1.10 | 0.15–0.25 |
| 4140 | 0.38–0.43 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.80–1.10 | 0.15–0.25 |
| 4142 | 0.40–0.45 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.80–1.10 | 0.15–0.25 |
| 4145 | 0.43–0.48 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.80–1.10 | 0.15–0.25 |
| 4147 | 0.45–0.50 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.80–1.10 | 0.15–0.25 |
| 4150 | 0.48–0.53 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.80–1.10 | 0.15–0.25 |
| 4320 | 0.17–0.22 | 0.45–0.65 | 0.040 | 0.040 | 0.15–0.35 | 1.65–2.00 | 0.40–0.60 | 0.20–0.30 |
| 4337 | 0.35–0.40 | 0.60–0.80 | 0.040 | 0.040 | 0.15–0.35 | 1.65–2.00 | 0.70–0.90 | 0.20–0.30 |
| E4337 | 0.35–0.40 | 0.65–0.85 | 0.025 | 0.025 | 0.15–0.35 | 1.65–2.00 | 0.70–0.90 | 0.20–0.30 |
| 4340 | 0.38–0.43 | 0.60–0.80 | 0.040 | 0.040 | 0.15–0.35 | 1.65–2.00 | 0.70–0.90 | 0.20–0.30 |
| E4340 | 0.38–0.43 | 0.65–0.85 | 0.025 | 0.025 | 0.15–0.35 | 1.65–2.00 | 0.70–0.90 | 0.20–0.30 |
| 4422 | 0.20–0.25 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | ... | 0.35–0.45 |
| 4427 | 0.24–0.29 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | ... | 0.35–0.45 |
| 4520 | 0.18–0.23 | 0.45–0.65 | 0.040 | 0.040 | 0.15–0.35 | ... | ... | 0.45–0.60 |
| 4615 | 0.13–0.18 | 0.45–0.65 | 0.040 | 0.040 | 0.15–0.35 | 1.65–2.00 | ... | 0.20–0.30 |
| 4617 | 0.15–0.20 | 0.45–0.65 | 0.040 | 0.040 | 0.15–0.35 | 1.65–2.00 | ... | 0.20–0.30 |
| 4620 | 0.17–0.22 | 0.45–0.65 | 0.040 | 0.040 | 0.15–0.35 | 1.65–2.00 | ... | 0.20–0.30 |
| 4621 | 0.18–0.23 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | 1.65–2.00 | ... | 0.20–0.30 |
| 4718 | 0.16–0.21 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | 0.90–1.20 | 0.35–0.55 | 0.30–0.40 |
| 4720 | 0.17–0.22 | 0.50–0.70 | 0.040 | 0.040 | 0.15–0.35 | 0.90–1.20 | 0.35–0.55 | 0.15–0.25 |
| 4815 | 0.13–0.18 | 0.40–0.60 | 0.040 | 0.040 | 0.15–0.35 | 3.25–3.75 | ... | 0.20–0.30 |
| 4817 | 0.15–0.20 | 0.40–0.60 | 0.040 | 0.040 | 0.15–0.35 | 3.25–3.75 | ... | 0.20–0.30 |

**TABLE 3** *Continued*

| Grade[A,B] Designation | Chemical Composition Limits, % | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Carbon | Manganese | Phosphorus,[C] max | Sulfur,[C,D] max | Silicon | Nickel | Chromium | Molybdenum |
| 4820 | 0.18–0.23 | 0.50–0.70 | 0.040 | 0.040 | 0.15–0.35 | 3.25–3.75 | ... | 0.20–0.30 |
| 5015 | 0.12–0.17 | 0.30–0.50 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.30–0.50 | ... |
| 5046 | 0.43–0.50 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.20–0.35 | ... |
| 5115 | 0.13–0.18 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.70–0.90 | ... |
| 5120 | 0.17–0.22 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.70–0.90 | ... |
| 5130 | 0.28–0.33 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.80–1.10 | ... |
| 5132 | 0.30–0.35 | 0.60–0.80 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.75–1.00 | ... |
| 5135 | 0.33–0.38 | 0.60–0.80 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.80–1.05 | ... |
| 5140 | 0.38–0.43 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.70–0.90 | ... |
| 5145 | 0.43–0.48 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.70–0.90 | ... |
| 5147 | 0.45–0.52 | 0.70–0.95 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.85–1.15 | ... |
| 5150 | 0.48–0.53 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.70–0.90 | ... |
| 5155 | 0.50–0.60 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.70–0.90 | ... |
| 5160 | 0.55–0.65 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.70–0.90 | ... |
| 52100[E] | 0.93–1.05 | 0.25–0.45 | 0.025 | 0.015 | 0.15–0.35 | ... | 1.35–1.60 | 0.10 max |
| E50100 | 0.95–1.10 | 0.25–0.45 | 0.025 | 0.025 | 0.15–0.35 | ... | 0.40–0.60 | ... |
| E51100 | 0.95–1.10 | 0.25–0.45 | 0.025 | 0.025 | 0.15–0.35 | ... | 0.90–1.15 | ... |
| E52100 | 0.95–1.10 | 0.25–0.45 | 0.025 | 0.025 | 0.15–0.35 | ... | 1.30–1.60 | ... |
| | | | | | | | | Vanadium |
| 6118 | 0.16–0.21 | 0.50–0.70 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.50–0.70 | 0.10–0.15 |
| 6120 | 0.17–0.22 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.70–0.90 | 0.10 min |
| 6150 | 0.48–0.53 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.80–1.10 | 0.15 min |
| | | | | | | Aluminum | | Molybdenum |
| E7140 | 0.38–0.43 | 0.50–0.70 | 0.025 | 0.025 | 0.15–0.40 | 0.95–1.30 | 1.40–1.80 | 0.30–0.40 |
| | | | | | | Nickel | | |
| 8115 | 0.13–0.18 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | 0.20–0.40 | 0.30–0.50 | 0.08–0.15 |
| 8615 | 0.13–0.18 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 8617 | 0.15–0.20 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 8620 | 0.18–0.23 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 8622 | 0.20–0.25 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 8625 | 0.23–0.28 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 8627 | 0.25–0.30 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 8630 | 0.28–0.33 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 8637 | 0.35–0.40 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 8640 | 0.38–0.43 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 8642 | 0.40–0.45 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 8645 | 0.43–0.48 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 8650 | 0.48–0.53 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 8655 | 0.50–0.60 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 8660 | 0.55–0.65 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 8720 | 0.18–0.23 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.20–0.30 |
| 8735 | 0.33–0.38 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.20–0.30 |
| 8740 | 0.38–0.43 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.20–0.30 |
| 8742 | 0.40–0.45 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.20–0.30 |
| 8822 | 0.20–0.25 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.30–0.40 |
| 9255 | 0.50–0.60 | 0.70–0.95 | 0.040 | 0.040 | 1.80–2.20 | ... | ... | ... |
| 9260 | 0.55–0.65 | 0.70–1.00 | 0.040 | 0.040 | 1.80–2.20 | ... | ... | ... |
| 9262 | 0.55–0.65 | 0.75–1.00 | 0.040 | 0.040 | 1.80–2.20 | ... | 0.25–0.40 | ... |
| E9310 | 0.08–0.13 | 0.45–0.65 | 0.025 | 0.025 | 0.15–0.35 | 3.00–3.50 | 1.00–1.40 | 0.08–0.15 |
| 9840 | 0.38–0.43 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | 0.85–1.15 | 0.70–0.90 | 0.20–0.30 |
| 9850 | 0.48–0.53 | 0.70–0.90 | 0.040 | 0.040 | 0.15–0.35 | 0.85–1.15 | 0.70–0.90 | 0.20–0.30 |
| 50B40 | 0.38–0.42 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.40–0.60 | ... |
| 50B44 | 0.43–0.48 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.40–0.60 | ... |
| 50B46 | 0.43–0.50 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.20–0.35 | ... |
| 50B50 | 0.48–0.53 | 0.74–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.40–0.60 | ... |

**TABLE 3** *Continued*

| Grade[A,B] Designation | Chemical Composition Limits, % | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Carbon | Manganese | Phosphorus,[C] max | Sulfur,[C,D] max | Silicon | Nickel | Chromium | Molybdenum |
| 50B60 | 0.55–0.65 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.40–0.60 | ... |
| 51B60 | 0.55–0.65 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | ... | 0.70–0.90 | ... |
| 81B45 | 0.43–0.48 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.20–0.40 | 0.35–0.55 | 0.08–0.15 |
| 86B45 | 0.43–0.48 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.40–0.70 | 0.40–0.60 | 0.15–0.25 |
| 94B15 | 0.13–0.18 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.30–0.60 | 0.30–0.50 | 0.08–0.15 |
| 94B17 | 0.15–0.20 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.30–0.60 | 0.30–0.50 | 0.08–0.15 |
| 94B30 | 0.28–0.33 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.30–0.60 | 0.30–0.50 | 0.08–0.15 |
| 94B40 | 0.38–0.43 | 0.75–1.00 | 0.040 | 0.040 | 0.15–0.35 | 0.30–0.60 | 0.30–0.50 | 0.08–0.15 |

[A] Grades shown in this table with prefix letter E generally are manufactured by the basic-electric-furnace process. All others are normally manufactured by the basic-open-hearth process but may be manufactured by the basic-electric-furnace process with adjustments in phosphorus and sulfur.

[B] Grades shown in this table with the letter B, such as 50B40, can be expected to have 0.0005 % minimum boron control.

[C] The phosphorus sulfur limitations for each process are as follows:

| | | | |
|---|---|---|---|
| Basic electric furnace | 0.025 max % | Acid electric furnace | 0.050 max % |
| Basic open hearth | 0.040 max % | Acid open hearth | 0.050 max % |

[D] Minimum and maximum sulfur content indicates resulfurized steels.

[E] The purchaser may specify the following maximum amounts: copper, 0.30 %; aluminum, 0.050 %; and oxygen, 0.0015 %.

## 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 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 Tubes shall be made by a seamless process and shall be either hot finished or cold finished, as specified.

4.6 Seamless tubing is a tubular product made without a welded seam. It is manufactured usually by hot working steel and, if necessary, by subsequently cold finishing the hot-worked tubular product to produce the desired shape, dimensions and properties.

## 5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1 (Low Carbon MT Grades), Table 2 (Higher Carbon Steels), Table 3 (Alloy Standard Steels) and Table 4 (Resulfurized or Rephosphorized, or Both, Carbon Steels).

5.2 Grade MT1015 or MTX1020 will be supplied at the producer's option, when no grade is specified.

5.3 When a carbon steel grade is ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Table 1 and Table 2 is not permitted.

5.4 Analyses of steels other than those listed are available. To determine their availability, the purchaser should contact the producer.

**TABLE 4 Chemical Requirements of Resulfurized or Rephosphorized, or Both, Carbon Steels[A]**

| Grade Designation | Chemical Composition Limits, % | | | | |
|---|---|---|---|---|---|
| | Carbon | Manganese | Phosphorus | Sulfur | Lead |
| 1118 | 0.14–0.20 | 1.30–1.60 | 0.040 max | 0.08–0.13 | |
| 11L18 | 0.14–0.20 | 1.30–1.60 | 0.040 max | 0.08–0.13 | 0.15–0.35 |
| 1132 | 0.27–0.34 | 1.35–1.65 | 0.040 max | 0.08–0.13 | |
| 1137 | 0.32–0.39 | 1.35–1.65 | 0.040 max | 0.08–0.13 | |
| 1141 | 0.37–0.45 | 1.35–1.65 | 0.040 max | 0.08–0.13 | |
| 1144 | 0.40–0.48 | 1.35–1.65 | 0.040 max | 0.24–0.33 | |
| 1213 | 0.13 max | 0.70–1.10 | 0.07–0.12 | 0.24–0.33 | |
| 12L14 | 0.15 max | 0.85–1.15 | 0.04–0.09 | 0.26–0.35 | 0.15–0.35 |
| 1215 | 0.09 max | 0.75–1.05 | 0.04–0.09 | 0.26–0.35 | |

[A] The ranges and limits given in this table apply to heat analysis; except as required by 6.1, product analyses are subject to the applicable additional tolerances given in Table Number 5.

## 6. Heat Analysis

6.1 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 used, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The heat analysis shall conform to the requirements specified, except that where the heat identity has not been maintained or where the analysis is not sufficiently complete to permit conformance to be determined, the chemical composition determined from a product analysis made by the tubular manufacturer shall conform to the requirements specified for heat analysis. When requested in the order or contract, a report of such analyses shall be furnished to the purchaser.

## 7. Product Analysis

7.1 Except as required by 6.1, a product analysis by the manufacturer shall be required only when requested in the order.

7.1.1 *Heat Identity Maintained*—One product analysis per heat on either billet or tube.

**TABLE 5 Product Analysis Tolerances Over or Under Specified Range or Limit**

NOTE 1—Individual determinations may vary from the specified heat limits or ranges to the extent shown in this table except that any element in a heat may not vary both above and below a specified range.

NOTE 2—In all types of steel, because of the degree to which phosphorus and sulfur segregate, product analysis for these elements is not technologically appropriate for rephosphorized or resulfurized steels unless misapplication is clearly indicated.

Carbon Steel Seamless Tubes

| Element | Limit, or Maximum of Specified Range, % | Tolerance, Over the Maximum Limit or Under the Minimum Limit, % | |
|---|---|---|---|
| | | Under min | Over max |
| Carbon | to 0.25, incl | 0.02 | 0.02 |
| | over 0.25 to 0.55, incl | 0.03 | 0.03 |
| | over 0.55 | 0.04 | 0.04 |
| Manganese | to 0.90, incl | 0.03 | 0.03 |
| | over 0.90 to 1.65, incl | 0.06 | 0.06 |
| Phosphorus | basic steel to 0.05, incl | . . . | 0.008 |
| | acid-bessemer steel to 0.12, incl | . . . | 0.010 |
| Sulfur | to 0.06, incl | . . . | 0.008 |
| Silicon | to 0.35, incl | 0.02 | 0.02 |
| | over 0.35 to 0.60, incl | 0.05 | 0.05 |
| Copper | . . . | 0.02 | 0.02 |

Alloy Steel Seamless Tube

| Elements | Limit, or Maximum of Specified Element, % | Tolerance Over Maximum Limit or Under Minimum Limit for Size Ranges Shown, % | |
|---|---|---|---|
| | | 100 in.$^2$ (645 cm$^2$) or less | Over 100 to 200 in.$^2$ (645 to 1290 cm$^2$), incl |
| Carbon | to 0.30, incl | 0.01 | 0.02 |
| | over 0.30 to 0.75, incl | 0.02 | 0.03 |
| | over 0.75 | 0.03 | 0.04 |
| Manganese | to 0.90, incl | 0.03 | 0.04 |
| | over 0.90 to 2.10, incl | 0.04 | 0.05 |
| Phosphorus | over max, only | 0.005 | 0.010 |
| Sulfur | to 0.060, incl | 0.005 | 0.010 |
| Silicon | to 0.35, incl | 0.02 | 0.02 |
| | over 0.35 to 2.20, incl | 0.05 | 0.06 |
| Nickel | to 1.00, incl | 0.03 | 0.03 |
| | over 1.00 to 2.00, incl | 0.05 | 0.05 |
| | over 2.00 to 5.30, incl | 0.07 | 0.07 |
| | over 5.30 to 10.00, incl | 0.10 | 0.10 |
| Chromium | to 0.90, incl | 0.03 | 0.04 |
| | over 0.90 to 2.10, incl | 0.05 | 0.06 |
| | over 2.10 to 3.99, incl | 0.10 | 0.10 |
| Molybdenum | to 0.20, incl | 0.01 | 0.01 |
| | over 0.20 to 0.40, incl | 0.02 | 0.03 |
| | over 0.40 to 1.15, incl | 0.03 | 0.04 |
| Vanadium | to 0.10, incl | 0.01 | 0.01 |
| | over 0.10 to 0.25, incl | 0.02 | 0.02 |
| | over 0.25 to 0.50, incl | 0.03 | 0.03 |
| | min value specified, check under min limit | 0.01 | 0.01 |
| Tungsten | to 1.00, incl | 0.04 | 0.05 |
| | over 1.00 to 4.00, incl | 0.08 | 0.09 |
| Aluminum | up to 0.10, incl | 0.03 | . . . |
| | over 0.10 to 0.20, incl | 0.04 | . . . |
| | over 0.20 to 0.30, incl | 0.05 | . . . |
| | over 0.30 to 0.80, incl | 0.07 | . . . |
| | over 0.80 to 1.80, incl | 0.10 | . . . |

7.1.2 *Heat Identity Not Maintained*—A product analysis from one tube per 2000 ft (610 m) or less for sizes over 3 in. (76.2 mm), and one tube per 5000 ft (1520 m) or less for sizes 3 in. (76.2 mm) and under.

7.2 Samples for chemical analysis, except for spectrochemical analysis, shall be taken in accordance with Practice E 59. The composition thus determined shall correspond to the requirements in the applicable section or Tables 1-5 of this specification and shall be reported to the purchaser or the purchaser's representative.

7.3 If the original test for check 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 the specification shall be rejected.

**TABLE 6 Outside Diameter Tolerances for Round Hot-Finished Tubing[A,B,C]**

| Outside Diameter Size Range, in. (mm) | Outside Diameter Tolerance, in. (mm) | |
|---|---|---|
| | Over | Under |
| Up to 2.999 (76.17) | 0.020 (0.51) | 0.020 (0.51) |
| 3.000–4.499 (76.20–114.27) | 0.025 (0.64) | 0.025 (0.64) |
| 4.500–5.999 (114.30–152.37) | 0.031 (0.79) | 0.031 (0.79) |
| 6.000–7.499 (152.40–190.47) | 0.037 (0.94) | 0.037 (0.94) |
| 7.500–8.999 (190.50–228.57) | 0.045 (1.14) | 0.045 (1.14) |
| 9.000–10.750 (228.60–273.05) | 0.050 (1.27) | 0.050 (1.27) |

[A] Diameter tolerances are not applicable to normalized and tempered or quenched and tempered conditions.

[B] The common range of sizes of hot finished tubes is 1½ in. (38.1 mm) to 10¾ in. (273.0 mm) outside diameter with wall thickness at least 3 % or more of outside diameter, but not less than 0.095 in. (2.41 mm).

[C] Larger sizes are available; consult manufacturer for sizes and tolerances.

## 8. Permissible Variations in Dimensions of Round Tubing

8.1 *Hot-Finished Mechanical Tubing*—Hot-finished mechanical tubing is produced to outside diameter and wall thickness. Variations in outside diameter and wall thickness shall not exceed the tolerances shown in Table 6and Table 7. Table 6 and Table 7 cover these tolerances and apply to the specified size.

8.2 *Cold-Worked Mechanical Tubing*:

8.2.1 Variations in outside diameter, inside diameter and wall thickness shall not exceed the tolerances shown in Table 8 and Table 9.

**TABLE 7 Wall Thickness Tolerances for Round Hot-Finished Tubing**

| Wall Thickness Range as Percent of Outside Diameter | Wall Thickness Tolerance,[A] percent Over and Under Nominal | | |
|---|---|---|---|
| | Outside Diameter 2.999 in. (76.19 mm) and smaller | Outside Diameter 3.000 in. (76.20 mm) to 5.999 in. (152.37 mm) | Outside Diameter 6.000 in. (152.40 mm) to 10.750 in. (273.05 mm) |
| Under 15 | 12.5 | 10.0 | 10.0 |
| 15 and over | 10.0 | 7.5 | 10.0 |

[A] Wall thickness tolerances may not be applicable to walls 0.199 in. (5.05 mm) and less; consult manufacturer for wall tolerances on such tube sizes.

**TABLE 8 Outside and Inside Diameter Tolerances for Round Cold-Worked Tubing[A,B,C]**

| Outside Diameter Size Range, in.[D] | Wall Thickness As Percent of Outside Diameter | Thermal Treatment after Final Cold Work Producing Size | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | None, or not exceeding 1100°F Nominal Temperature | | | | Heated Above 1100°F Nominal Temperature Without Accelerated Cooling | | | | Quenched and Tempered | | | |
| | | OD, in.[D] | | ID, in.[D] | | OD, in.[D] | | ID, in.[D] | | OD, in.[D] | | ID, in.[D] | |
| | | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under | Over | Under |
| Up to 0.499 | all | 0.004 | 0.000 | — | — | 0.005 | 0.002 | — | — | 0.010 | 0.010 | 0.010 | 0.010 |
| 0.500–1.699 | all | 0.005 | 0.000 | 0.000 | 0.005 | 0.007 | 0.002 | 0.002 | 0.007 | 0.015 | 0.015 | 0.015 | 0.015 |
| 1.700–2.099 | all | 0.006 | 0.000 | 0.000 | 0.006 | 0.006 | 0.005 | 0.005 | 0.006 | 0.020 | 0.020 | 0.020 | 0.020 |
| 2.100–2.499 | all | 0.007 | 0.000 | 0.000 | 0.007 | 0.008 | 0.005 | 0.005 | 0.008 | 0.023 | 0.023 | 0.023 | 0.023 |
| 2.500–2.899 | all | 0.008 | 0.000 | 0.000 | 0.008 | 0.009 | 0.005 | 0.005 | 0.009 | 0.025 | 0.025 | 0.025 | 0.025 |
| 2.900–3.299 | all | 0.009 | 0.000 | 0.000 | 0.009 | 0.011 | 0.005 | 0.005 | 0.011 | 0.028 | 0.028 | 0.028 | 0.028 |
| 3.300–3.699 | all | 0.010 | 0.000 | 0.000 | 0.010 | 0.013 | 0.005 | 0.005 | 0.013 | 0.030 | 0.030 | 0.030 | 0.030 |
| 3.700–4.099 | all | 0.011 | 0.000 | 0.000 | 0.011 | 0.013 | 0.007 | 0.010 | 0.010 | 0.033 | 0.033 | 0.033 | 0.033 |
| 4.100–4.499 | all | 0.012 | 0.000 | 0.000 | 0.012 | 0.014 | 0.007 | 0.011 | 0.011 | 0.036 | 0.036 | 0.036 | 0.036 |
| 4.500–4.899 | all | 0.013 | 0.000 | 0.000 | 0.013 | 0.016 | 0.007 | 0.012 | 0.012 | 0.038 | 0.038 | 0.038 | 0.038 |
| 4.900–5.299 | all | 0.014 | 0.000 | 0.000 | 0.014 | 0.018 | 0.007 | 0.013 | 0.013 | 0.041 | 0.041 | 0.041 | 0.041 |
| 5.300–5.549 | all | 0.015 | 0.000 | 0.000 | 0.015 | 0.020 | 0.007 | 0.014 | 0.014 | 0.044 | 0.044 | 0.044 | 0.044 |
| 5.550–5.559 | under 6 | 0.010 | 0.010 | 0.010 | 0.010 | 0.018 | 0.018 | 0.018 | 0.018 | | | | |
| | 6 to 7½ | 0.009 | 0.009 | 0.009 | 0.009 | 0.016 | 0.016 | 0.016 | 0.016 | | | | |
| | over 7½ | 0.018 | 0.000 | 0.009 | 0.009 | 0.017 | 0.015 | 0.016 | 0.016 | | | | |
| 6.000–6.499 | under 6 | 0.013 | 0.013 | 0.013 | 0.013 | 0.023 | 0.023 | 0.023 | 0.023 | | | | |
| | 6 to 7½ | 0.010 | 0.010 | 0.010 | 0.010 | 0.018 | 0.018 | 0.018 | 0.018 | | | | |
| | over 7½ | 0.020 | 0.000 | 0.010 | 0.010 | 0.020 | 0.015 | 0.018 | 0.018 | | | | |
| 6.500–6.999 | under 6 | 0.015 | 0.015 | 0.015 | 0.015 | 0.027 | 0.027 | 0.027 | 0.027 | | | | |
| | 6 to 7½ | 0.012 | 0.012 | 0.012 | 0.012 | 0.021 | 0.021 | 0.021 | 0.021 | | | | |
| | over 7½ | 0.023 | 0.000 | 0.012 | 0.012 | 0.026 | 0.015 | 0.021 | 0.021 | | | | |
| 7.000–7.499 | under 6 | 0.018 | 0.018 | 0.018 | 0.018 | 0.032 | 0.032 | 0.032 | 0.032 | | | | |
| | 6 to 7½ | 0.013 | 0.013 | 0.013 | 0.013 | 0.023 | 0.023 | 0.023 | 0.023 | | | | |
| | over 7½ | 0.026 | 0.000 | 0.013 | 0.013 | 0.031 | 0.015 | 0.023 | 0.023 | | | | |
| 7.500–7.999 | under 6 | 0.020 | 0.020 | 0.020 | 0.020 | 0.035 | 0.035 | 0.035 | 0.035 | | | | |
| | 6 to 7½ | 0.015 | 0.015 | 0.015 | 0.015 | 0.026 | 0.026 | 0.026 | 0.026 | | | | |
| | over 7½ | 0.029 | 0.000 | 0.015 | 0.015 | 0.036 | 0.015 | 0.026 | 0.026 | | | | |
| 8.000–8.499 | under 6 | 0.023 | 0.023 | 0.023 | 0.023 | 0.041 | 0.041 | 0.041 | 0.041 | | | | |
| | 6 to 7½ | 0.016 | 0.016 | 0.016 | 0.016 | 0.028 | 0.028 | 0.028 | 0.028 | | | | |
| | over 7½ | 0.031 | 0.000 | 0.015 | 0.016 | 0.033 | 0.022 | 0.028 | 0.028 | | | | |
| 8.500–8.999 | under 6 | 0.025 | 0.025 | 0.025 | 0.025 | 0.044 | 0.044 | 0.044 | 0.044 | | | | |
| | 6 to 7½ | 0.017 | 0.017 | 0.017 | 0.017 | 0.030 | 0.030 | 0.030 | 0.030 | | | | |
| | over 7½ | 0.034 | 0.000 | 0.015 | 0.019 | 0.038 | 0.022 | 0.030 | 0.030 | | | | |
| 9.000–9.499 | under 6 | 0.028 | 0.028 | 0.028 | 0.028 | 0.045 | 0.045 | 0.049 | 0.049 | | | | |
| | 6 to 7½ | 0.019 | 0.019 | 0.019 | 0.019 | 0.033 | 0.033 | 0.033 | 0.033 | | | | |
| | over 7½ | 0.037 | 0.000 | 0.015 | 0.022 | 0.043 | 0.022 | 0.033 | 0.033 | | | | |
| 9.500–9.999 | under 6 | 0.030 | 0.030 | 0.030 | 0.030 | 0.045 | 0.045 | 0.053 | 0.053 | | | | |
| | 6 to 7½ | 0.020 | 0.020 | 0.020 | 0.020 | 0.035 | 0.035 | 0.035 | 0.035 | | | | |
| | over 7½ | 0.040 | 0.000 | 0.015 | 0.025 | 0.048 | 0.022 | 0.035 | 0.035 | | | | |
| 10.000–10.999 | under 6 | 0.034 | 0.034 | 0.034 | 0.034 | 0.045 | 0.045 | 0.060 | 0.060 | | | | |
| | 6 to 7½ | 0.022 | 0.022 | 0.022 | 0.022 | 0.039 | 0.039 | 0.039 | 0.039 | | | | |
| | over 7½ | 0.044 | 0.000 | 0.015 | 0.029 | 0.055 | 0.022 | 0.039 | 0.039 | | | | |
| 11.000–12.000 | under 6 | 0.035 | 0.035 | 0.035 | 0.035 | 0.050 | 0.050 | 0.065 | 0.065 | | | | |
| | 6 to 7½ | 0.025 | 0.025 | 0.025 | 0.025 | 0.045 | 0.045 | 0.045 | 0.045 | | | | |
| | over 7½ | 0.045 | 0.000 | 0.015 | 0.035 | 0.060 | 0.022 | 0.045 | 0.045 | | | | |

[A] Many tubes with inside diameter less than 50 % of outside diameter or with wall thickness more than 25 % of outside diameter, or with wall thickness over 1¼ in., or weighing more than 90 lb/ft, are difficult to draw over a mandrel. Therefore, the inside diameter can vary over or under by an amount equal to 10 % of the wall thickness. See also Footnote *B*.

[B] For those tubes with inside diameter less than ½ in. (or less than ⅝ in. 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, for those tubes, the inside diameter is governed by the outside diameter tolerance shown in this table and the wall thickness tolerances shown in Table Number 9.

[C] Tubing having a wall thickness less than 3 % of the outside diameter cannot be straightened properly without a certain amount of distortion. Consequently such tubes, while having an average outside diameter and inside diameter within the tolerances shown in this table, require an ovality tolerance of ½ % over and under nominal outside diameter, this being in addition to the tolerances indicated in this table.

[D] 1 in. = 25.4 mm.

8.2.2 Cold-worked mechanical tubing is normally produced to outside diameter and wall thickness. If the inside diameter is a more important dimension, then cold-worked tubing should be specified to inside diameter and wall thickness or outside diameter and inside diameter.

8.3 *Rough-Turned Mechanical Tubing*—Variation in outside diameter and wall thickness shall not exceed the tolerance in Table 10. Table 10 covers tolerances as applied to outside diameter and wall thickness and applies to the specified size.

8.4 *Ground Mechanical Tubing*—Variation in outside diameter shall not exceed the tolerances in Table 11. This product is normally produced from a cold-worked tube.

8.5 *Lengths*—Mechanical tubing is commonly furnished in mill lengths, 5 ft (1.5 m) and over. Definite cut lengths are

**TABLE 9 Wall Thickness Tolerances for Round Cold-Worked Tubing**

| Wall Thickness Range as % of Outside Diameter | Wall Thickness Tolerance Over and Under Nominal, % | |
|---|---|---|
| | Up to 1.499 in., ID | 1.500 in. and Over |
| 25 and Under | 10.0 | 7.5 |
| Over 25 | 12.5 | 10.0 |

**TABLE 10 Outside Diameter and Wall Tolerances for Rough-Turned Seamless Steel Tubing**

| Specified Size Outside Diameter, in. (mm) | Outside Diameter, in. (mm) | | Wall Thickness, % | |
|---|---|---|---|---|
| | Plus | Minus | Plus | Minus |
| Up to but not including 6¾ (171.4) | 0.005 (0.13) | 0.005 (0.13) | 12.5 | 12.5 |
| 6¾ to 8 (171.4 to 203.2) | 0.010 (0.25) | 0.010 (0.25) | 12.5 | 12.5 |

**TABLE 11 Outside Diameter Tolerances for Ground Seamless Tubing**

NOTE 1—The wall thickness and inside diameter tolerances are the same as for cold-worked mechanical tubing tolerances given in Table Number 8.

| Size Outside Diameter, in. (mm) | Outside Diameter Tolerances for Sizes and Lengths Given, in. (mm) | | | |
|---|---|---|---|---|
| | Over | Under | Over | Under |
| | Lengths up to 16 ft (4.9 m), incl | | Lengths over 16 ft (4.9 m) | |
| Up to 1¼ (31.8), incl | 0.003 (0.08) | 0.000 | 0.004 (0.10) | 0.000 |
| Over 1¼ to 2 (31.8 to 50.8), incl | 0.005 (0.13) | 0.000 | 0.006 (0.15) | 0.000 |
| | Over | Under | Over | Under |
| | Lengths up to 12 ft (3.7 m), incl | | Lengths to 16 ft (4.9 m) | |
| Over 2 to 3 (50.8 to 76.2), incl | 0.005 (0.13) | 0.000 | 0.006 (0.15) | 0.000 |
| Over 3 to 4 (76.2 to 101.6), incl | 0.006 (0.15) | 0.000 | 0.008 (0.20) | 0.000 |

furnished when specified by the purchaser. Length tolerances are shown in Table 12.

8.6 *Straightness*—The straightness tolerances for seamless round tubing shall not exceed the amounts shown in Table 13.

## 9. Permissible Variations in Dimensions of Square and Rectangular Tubing

9.1 Variations in outside dimensions and wall thickness shall not exceed the tolerances shown in Table 14 unless otherwise specified by the manufacturer and the purchaser. The wall thickness dimensions shall not apply at the corners.

9.2 *Corner Radii*—The corners of a square and a rectangular tube will be slightly rounded inside and rounded outside consistent with the wall thickness. The outside corner may be slightly flattened. The radii of corners for square and rectangular cold finished tubing shall be in accordance with Table 15.

9.3 *Squareness Tolerance*:

**TABLE 12 Length Tolerances for Round Hot-Finished or Cold-Finished Tubing**

NOTE 1—The producer should be consulted for length tolerances for tubes produced by liquid- or air-quenching heat treatment.

| Length, ft (m) | Outside Diameter, in. (mm) | Tolerance, in. (mm) | |
|---|---|---|---|
| | | Over | Under |
| 4 (1.2) and under | up to 2 (50.8), incl | 1/16 (1.6) | 0 |
| 4 (1.2) and under | over 2 to 4 (50.8 to 101.6), incl | 3/32 (2.4) | 0 |
| 4 (1.2) and under | over 4 (101.6) | 1/8 (3.2) | 0 |
| Over 4 to 10 (1.2 to 3.0), incl | up to 2 (50.8), incl | 3/32 (2.4) | 0 |
| Over 4 to 10 (1.2 to 3.0), incl | over 2 (50.8) | 1/8 (3.2) | 0 |
| Over 10 to 24 (3.0 to 7.3), incl | all sizes | 3/16 (4.8) | 0 |
| Over 24 (7.3) | all sizes | 3/16 + 1/2 (4.8 to 12.7) for each 10 ft (3.0 m) or fraction over 24 ft (7.3 m) | 0 |

9.3.1 Permissible variations for squareness for the side of square and rectangular tubing shall be determined by the following equation:

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

where:

$b$ = tolerance for out-of-square, in. (mm), and
$c$ = largest external dimension across flats, in. (mm).

9.3.2 The squareness of sides is commonly determined by one of the following methods:

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

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

9.4 *Twist Tolerance*:

9.4.1 Twist tolerance for square and rectangular tubing shall be in accordance with Table 16. The twist tolerance in square and rectangular tubing may be measured by holding one end of the square or rectangular tube on a surface plate with the bottom side parallel to the surface plate and noting the height at either corner of the opposite end of the same side above the surface plate.

9.4.2 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.

9.5 *Lengths*—Square and rectangular tubing is commonly furnished in mill lengths 5 ft (1.5 m) and over. Definite cut lengths are furnished when specified by the purchaser. Length tolerances are shown in Table 17.

9.6 *Straightness*—Straightness for square and rectangular tubing shall be 0.060 in. in any 3 ft (1.67 mm in 1 m).

## 10. Machining Allowances

10.1 For the method of calculating the tube size required to cleanup in machining to a particular finished part, see Appendix X1.

**TABLE 13 Straightness Tolerances for Seamless Round Mechanical Tubing**

NOTE 1—The straightness variation for any 3 ft (0.9 m) of length is determined by measuring the concavity between the tube and a 3-ft straightedge with a feeler gage. The total variation, that is, the maximum curvature at any point in the total length of tube, is determined by rolling the tube on a surface plate and measuring the concavity with a feeler gage.

NOTE 2—The tolerances apply generally to unannealed, finish-annealed, and medium-annealed cold-finished or hot-finished tubes. When straightening stress would interfere with the use of the end product, the straightness tolerances shown do not apply when tubing is specified "not to be straightened after furnace treatment.'' These straightness tolerances do not apply to soft-annealed or quenched and tempered tubes.

| Size Limits | Maximum Curvature in any 3 ft/in. (mm/m) | Maximum Curvature in Total Lengths, in. (mm) | Maximum Curvature for Lengths under 3 ft or 1 m |
|---|---|---|---|
| OD 5 in. (127.0 mm) and smaller. Wall thickness, over 3 % of OD | 0.030 (0.83) | 0.030 × (no. of ft of length/3) (0.83 × no. of m of length) | ratio of 0.010 in./ft or 0.83 mm/m |
| OD over 5 to 8 in. (127.0 to 203.2 mm), incl. Wall thickness, over 4 % of OD | 0.045 (1.25) | 0.045 × (no. of ft of length/3) (1.25 × no. of m of length) | ratio of 0.015 in./ft or 1.25 mm/m |
| OD over 8 to 12¾ in. (203.2 to 323.8 mm), incl. Wall thickness, over 4 % of OD | 0.060 (1.67) | 0.060 × (no. of ft of length/3) (1.67 × no. of m of length) | ratio of 0.020 in./ft or 16.7 mm/m |

**TABLE 14 Tolerances for Outside Dimensions and Wall Thickness of Square and Rectangular Cold-Finished Tubing**

| Largest Outside Dimension across Flats, in. (mm) | Wall Thickness, in. (mm) | Tolerances for Outside Dimensions including Convexity or Concavity | Wall Thickness Tolerance, Plus and Minus, % |
|---|---|---|---|
| To ¾ (19.0), incl | 0.065 (1.65) and lighter | ±0.015 in. (0.38 mm) | 10 |
| To ¾ (19.0), incl | over 0.065 (1.65) | ±0.010 in. (0.25 mm) | 10 |
| Over ¾ to 1¼ (19.0 to 31.8), incl | all thicknesses | ±0.015 in. (0.38 mm) | 10 |
| Over 1¼ to 2½ (31.8 to 63.5), incl | all thicknesses | ±0.020 in. (0.51 mm) | 10 |
| Over 2½ to 3½ (63.5 to 88.9), incl | 0.065 (1.65) and lighter | ±0.030 in. (0.76 mm) | 10 |
| Over 2½ to 3½ (63.5 to 88.9), incl | over 0.065 (1.65) | ±0.025 in. (0.64 mm) | 10 |
| Over 3½ to 5½ (88.9 to 139.7), incl | all thicknesses | ±0.030 in. (0.76 mm) | 10 |
| Over 5½ to 7½ (139.7 to 190.5), incl | all thicknesses | ±1 % | 10 |

**TABLE 15 Corner Radii of Square and Rectangular Cold-Finished Tubing**

| Wall Thickness, in. (mm) | Maximum Radii of Corners, in. (mm) |
|---|---|
| Over 0.020 to 0.049 (0.51 to 1.24), incl | 3/32 (2.4) |
| Over 0.049 to 0.065 (1.24 to 1.65), incl | 1/8 (3.2) |
| Over 0.065 to 0.083 (1.65 to 2.11), incl | 9/64 (3.6) |
| Over 0.083 to 0.095 (2.11 to 2.41), incl | 3/16 (4.8) |
| Over 0.095 to 0.109 (2.41 to 2.77), incl | 13/64 (5.2) |
| Over 0.109 to 0.134 (2.77 to 3.40), incl | 7/32 (5.6) |
| Over 0.134 to 0.156 (3.40 to 3.96), incl | 1/4 (6.4) |
| Over 0.156 to 0.188 (3.96 to 4.78), incl | 9/32 (7.1) |
| Over 0.188 to 0.250 (4.78 to 6.35), incl | 11/32 (8.7) |
| Over 0.250 to 0.313 (6.35 to 7.95), incl | 7/16 (11.1) |
| Over 0.313 to 0.375 (7.95 to 9.52), incl | 1/2 (12.7) |
| Over 0.375 to 0.500 (9.52 to 12.70), incl | 11/16 (17.5) |
| Over 0.500 to 0.625 (12.70 to 15.88), incl | 27/32 (21.4) |

**TABLE 16 Twist Tolerance of Square and Rectangular Cold-Finished Tubing**

NOTE 1—The twist in square and rectangular tubing is measured by holding one end of the tubing on a surface plate and noting the height of either corner of the opposite end of the same side above the surface plate.

| Largest Dimension, in. (mm) | Twist Tolerance in 3 ft, in. (mm/m) |
|---|---|
| Under ½ (12.7) | 0.050 (13.8) |
| ½ to 1½ (12.7 to 38.1), incl | 0.075 (20.8) |
| Over 1½ to 2½ (38.1 to 63.5), incl | 0.095 (26.2) |
| Over 2½ to 4 (63.5 to 101.6), incl | 0.125 (34.5) |

**TABLE 17 Length Tolerances When Exact Lengths Are Specified for Square and Rectangular Tubing**

| Length, ft (m) | Tolerance, in. (mm) | |
|---|---|---|
| | Plus | Minus |
| 1 to 4 (0.3 to 1.2), incl | 1/8 (3.2) | 0 |
| Over 4 to 12 (1.2 to 3.7), incl | 3/16 (4.8) | 0 |
| Over 12 (3.7) | 1/4 (6.4) | 0 |

## 11. Workmanship, Finish, and Appearance

11.1 The tubing shall be free of laps, cracks, seams, and other defects as is consistent with good commercial practice. The surface finish will be compatible with the condition to which it is ordered.

## 12. Condition

12.1 The purchaser shall specify a sizing method and, if required, a thermal treatment.

12.1.1 *Sizing Methods*:

12.1.1.1 HF—Hot Finished,

12.1.1.2 CW—Cold Worked,

12.1.1.3 RT—Rough Turned,

12.1.1.4 G—Ground.

12.1.2 *Thermal Treatments*:

12.1.2.1 A—Annealed,

12.1.2.2 N—Normalized,

12.1.2.3 QT—Quenched and Tempered,

12.1.2.4 SR—Stress Relieved or Finish Anneal.

## 13. Coating

13.1 When specified, tubing shall be coated with a film of oil before shaping to retard rust. Should the order specify that tubing be shipped without rust retarding oil, the film of oils incidental to manufacture will remain on the surface. If the order specifies no oil, the purchaser assumes responsibility for rust in transit.

13.2 Unless otherwise specified, tubing may be coated with a rust retarding oil on the outside and inside surfaces, at the option of the manufacturer.

## 14. Rejection

14.1 Tubes that fail to meet the requirements of this specification shall be set aside and the manufacturer shall be notified.

## 15. Product and Package Marking

15.1 *Civilian Procurement*—Each box, bundle or lift, and, when individual pieces are shipped, each piece shall be identified by a tag or stencil with the manufacturer's name or brand, specified size, grade, purchaser's order number and this specification number (ASTM A 519).

15.2 In addition to the requirements in 15.1 and 15.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

15.3 *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.

## 16. Packaging

16.1 *Civilian Procurement*—On tubing 0.065 in. (1.65 mm) and lighter, the manufacturer, at his option, will box, crate, carton, package in secured lifts, or bundle to ensure safe delivery. Tubing heavier than 0.065 in. will normally be shipped loose, bundled or in secured lifts. Special packaging requiring extra operations other than those normally used by a manufacturer must be specified in the order.

16.2 *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.

## 17. Keywords

17.1 alloy steel tube; carbon steel tube; mechanical tubing; seamless 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. Mechanical tests shall be performed in accordance with the applicable sections of Test Methods and Definitions A 370.

## S1. Special Smooth Inside Surface

S1.1 This tubing is intended for use where the inside surface is of prime importance and no stock removal by the user is contemplated. This product differs from conventional mechanical tubing in that special processing or selection, or both, are necessary to obtain the required surface. Light scores and pits within the limits shown in Table S1 are customarily allowable.

## S2. Mechanical Requirements

S2.1 *Hardness Test:*

S2.1.1 When hardness limits are required, the manufacturer shall be consulted. Typical hardnesses are listed in Table S2.

S2.1.2 When specified, the hardness test shall be performed on 1 % of the tubes.

S2.2 *Tension Tests:*

S2.2.1 When tensile properties are required, the manufacturer shall be consulted. Typical tensile properties for some of the more common grades and thermal conditions are listed in Table S2.

**TABLE S1 Special Smooth Finish Tubes Allowance for Surface Imperfections**

| Size, Outside Diameter, in. (mm) | Wall Thickness, in. (mm) | Wall Depth Allowance for Surface Imperfection, in. (mm) | |
|---|---|---|---|
| | | Scores | Pits |
| ⅝ to 2½ (15.8 to 63.5), incl | 0.065 to 0.109 (1.65 to 2.77) | 0.001 (0.03) | 0.0015 (0.038) |
| | over 0.109 to ¼ (2.77 to 6.4), incl | 0.001 (0.03) | 0.002 (0.05) |
| Over 2½ to 5½ (63.5 to 139.7), excl | 0.083 to ⅛ (2.11 to 3.2), incl | 0.0015 (0.038) | 0.0025 (0.064) |
| | over ⅛ to 3⁄16 (3.2 to 4.8), incl | 0.0015 (0.038) | 0.003 (0.08) |
| | over 3⁄16 to ⅜ (4.8 to 9.5), incl | 0.002 (0.05) | 0.004 (0.10) |
| 5½ to 8 (139.7 to 203.2), excl | ⅛ to ¼ (3.2 to 6.4), incl | 0.0025 (0.064) | 0.005 (0.13) |
| | over ¼ to ½ (6.4 to 12.7), incl | 0.003 (0.08) | 0.006 (0.15) |

**TABLE S2 Typical Tensile Properties, Hardness and Thermal Condition for some of the More Common Grades of Carbon and Alloy Steels**

| Grade Designation | Condition[A] | Ultimate Strength, | | Yield Strength, | | Elongation in 2 in. or 50 mm, % | Rockwell, Hardness B Scale |
|---|---|---|---|---|---|---|---|
| | | ksi | MPa | ksi | MPa | | |
| 1020 | HR | 50 | 345 | 32 | 221 | 25 | 55 |
| | CW | 70 | 483 | 60 | 414 | 5 | 75 |
| | SR | 65 | 448 | 50 | 345 | 10 | 72 |
| | A | 48 | 331 | 28 | 193 | 30 | 50 |
| | N | 55 | 379 | 34 | 234 | 22 | 60 |
| 1025 | HR | 55 | 379 | 35 | 241 | 25 | 60 |
| | CW | 75 | 517 | 65 | 448 | 5 | 80 |
| | SR | 70 | 483 | 55 | 379 | 8 | 75 |
| | A | 53 | 365 | 30 | 207 | 25 | 57 |
| | N | 55 | 379 | 36 | 248 | 22 | 60 |
| 1035 | HR | 65 | 448 | 40 | 276 | 20 | 72 |
| | CW | 85 | 586 | 75 | 517 | 5 | 88 |
| | SR | 75 | 517 | 65 | 448 | 8 | 80 |
| | A | 60 | 414 | 33 | 228 | 25 | 67 |
| | N | 65 | 448 | 40 | 276 | 20 | 72 |
| 1045 | HR | 75 | 517 | 45 | 310 | 15 | 80 |
| | CW | 90 | 621 | 80 | 552 | 5 | 90 |
| | SR | 80 | 552 | 70 | 483 | 8 | 85 |
| | A | 65 | 448 | 35 | 241 | 20 | 72 |
| | N | 75 | 517 | 48 | 331 | 15 | 80 |
| 1050 | HR | 80 | 552 | 50 | 345 | 10 | 85 |
| | SR | 82 | 565 | 70 | 483 | 6 | 86 |
| | A | 68 | 469 | 38 | 262 | 18 | 74 |
| | N | 78 | 538 | 50 | 345 | 12 | 82 |
| 1118 | HR | 50 | 345 | 35 | 241 | 25 | 55 |
| | CW | 75 | 517 | 60 | 414 | 5 | 80 |
| | SR | 70 | 483 | 55 | 379 | 8 | 75 |
| | A | 50 | 345 | 30 | 207 | 25 | 55 |
| | N | 55 | 379 | 35 | 241 | 20 | 60 |
| 1137 | HR | 70 | 483 | 40 | 276 | 20 | 75 |
| | CW | 80 | 552 | 65 | 448 | 5 | 85 |
| | SR | 75 | 517 | 60 | 414 | 8 | 80 |
| | A | 65 | 448 | 35 | 241 | 22 | 72 |
| | N | 70 | 483 | 43 | 296 | 15 | 75 |
| 4130 | HR | 90 | 621 | 70 | 483 | 20 | 89 |
| | SR | 105 | 724 | 85 | 586 | 10 | 95 |
| | A | 75 | 517 | 55 | 379 | 30 | 81 |
| | N | 90 | 621 | 60 | 414 | 20 | 89 |
| 4140 | HR | 120 | 855 | 90 | 621 | 15 | 100 |
| | SR | 120 | 855 | 100 | 689 | 10 | 100 |
| | A | 80 | 552 | 60 | 414 | 25 | 85 |
| | N | 120 | 855 | 90 | 621 | 20 | 100 |

[A] The following are the symbol definitions for the various conditions:
HR—Hot Rolled
CW—Cold Worked
SR—Stress Relieved
A—Annealed
N—Normalized

S2.2.2 When the tension test is specified, one test will be performed on a specimen from one tube per 2000 ft (610 m) or less for sizes over 3 in. (76.2 mm) and one tube per 5000 ft (1520 m) or less for sizes 3 in. (76.2 mm) and under.

S2.2.3 The yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen or to a total extension of 0.5 % of the gage length under load shall be determined.

S2.3 *Nondestructive Tests*—Various types of nondestructive ultrasonic or electromagnetic tests are available. The test to be used and the inspection limits shall be established by manufacturer and purchaser agreement.

S2.4 *Steel Cleanliness*—When there are special requirements for steel cleanliness, the methods of test and limits of acceptance shall be established by manufacturer and purchaser agreement.

S2.5 *Hardenability*—Any requirement for H-steels, tests and test limits shall be specified in the purchase order.

S2.6 *Flaring Test:*

S2.6.1 When tubing suitable for flaring is required, the manufacturer shall be consulted. When the grade and thermal treatment are suitable for flaring, a section of tube approximately 4 in. (101.6 mm) in length shall stand being flared with a tool having a 60° included angle until the tube at the mouth of the flare has been expanded 15 % of the inside diameter without cracking or showing flaws.

S2.6.2 When the flaring test is specified, tests shall be performed on two specimens/5000 ft (1520 m) or less.

## S3. Certification for Government Orders

S3.1 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 specification 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.

## S4. Rejection Provisions for Government Orders

S4.1 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.

S4.2 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 material shall be a matter for agreement.

## APPENDIX

**(Nonmandatory Information)**

### X1. MACHINING ALLOWANCES FOR ROUND TUBING

X1.1 Seamless mechanical tubing is produced either hot finished or cold worked. Hot-finished tubes are specified to outside diameter and wall thickness. Cold-worked tubing is specified to two of the three dimensions; outside diameter, inside diameter and wall thickness.

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

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 an important factor on the higher carbon grades of steel. Decarburization limits are shown in various specifications. For example, the decarburization limits for bearing steels are shown in ASTM specifications, and for aircraft steel 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. (76.2 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 11 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. (76.2 to 139.7 mm) excl, plus and minus 0.031 in. (0.79 mm) or 0.062 in. (1.55 mm)). If machined true to the inside diameter, outside diameter tolerances are not used in this step. Cold-worked tolerances are shown in Table 8. Hot-finished tolerances are shown in Table 6. The calculated maximum outside diameter is obtained by adding allowances given in 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 (finish 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. Decarburization limits are shown in various specifications. For example, the decarburization limits for bearing steels are shown in ASTM specifications and for aircraft 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 8. Hot-finished tolerances (use outside diameter tolerances for inside diameter for calculating purposes) are shown in Table 6. The calculated minimum inside X1 diameter is obtained by subtracting the sum 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 ±10 % for cold-worked tubing and ±12.5 % 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 either the outside diameter or 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 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 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 8) is added to the inside diameter obtained in Step 2.

X1.7.3 *Hot-Finish Machined True to Outside Diameter*—From the size obtained in Step 1, subtract one half the total tolerance (shown in Table 6) 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-Finish 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) 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 standard since the last issue (A 519 – 96 (2001)) that may impact the use of this standard. (Approved September 10, 2003)

(*1*) Table 3 was revised to add grade 52100.