



Designation: ~~A 513-00~~ Designation: A 513 - 06

Standard Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing¹

This standard is issued under the fixed designation A 513; 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.

1. Scope*

- 1.1 This specification covers electric-resistance-welded carbon and alloy steel tubing for use as mechanical tubing.
- 1.2 This specification covers mechanical tubing made from hot- or cold-rolled steel.
- 1.3 This specification covers round, square, rectangular, and special shape tubing.

Type	Size Range (Round Tubing)
Electric-Resistance-Welded Tubing from Hot-Rolled Steel	outside diameter from $\frac{1}{2}$ to 15 in. (19.0 to 381.0 mm) wall from 0.065 to 0.650 in. (1.65 to 16.50 mm)
Electric-Resistance-Welded Tubing from Cold-Rolled Steel	outside diameter from $\frac{3}{8}$ to 12 in. (9.92 to 304.8 mm) wall from 0.022 to 0.134 in. (0.71 to 3.40 mm)

- 1.4 Optional supplementary requirements 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.

2. Referenced Documents

2.1 ASTM Standards:²

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- E 1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition
- E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
- E 273 Practice for Ultrasonic Examination of Longitudinal the Weld Zone of Welded Pipe and Tubing
- E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation
- E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 ANSI Standard:

- B 46.1 Surface Texture³

2.3 Military Standards:

- MIL-STD-129 Marking for Shipment and Storage⁴
- MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage⁴

2.4 Federal Standard:

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

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 Annual Book of ASTM Standards, Vol 01.03.

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 Annual Book of ASTM Standards, Vol 03.06.

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

⁴ Annual Book of ASTM Standards, Vol 03.03.

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. Ordering Information

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

- 3.1.1 Quantity (feet or number of lengths),
- 3.1.2 Name of material (electric resistance-welded carbon or alloy steel mechanical tubing),
- 3.1.3 Type, description and code letters, (Section 1 and 12.1),
- 3.1.4 Thermal condition, (12.2),
- 3.1.5 Flash condition, (12.3),
- 3.1.6 Grade designation, if required, (Section 5),
- 3.1.7 Report chemical analysis and product analysis, if required (Sections 6 and 7),
- 3.1.8 Individual supplementary requirements, if required (S1 to S10, inclusive),
- 3.1.9 Cross section (round, square, rectangular and special shapes),
- 3.1.10 Dimensions, round, outside and inside and wall thickness (see 8.1 and 8.2) or square and rectangular, outside dimension and wall thickness and corner radii, if required (see 9.1 and 9.2),
- 3.1.11 Surface finish (see 11.2),
- 3.1.12 Length, round, mill lengths or definite cut length (see 8.3), square and rectangular, specified length (see 9.4),
- 3.1.13 Squareness of cut, round tubing, if required, (see 8.4),
- 3.1.14 Burrs removed, if required (see 11.3),
- 3.1.15 Protective coating (see 14.1),
- 3.1.16 Special packaging (see 17.1),
- 3.1.17 Specification designation,
- 3.1.18 End use,
- 3.1.19 Special requirements,
- 3.1.20 Special marking (Section 16), and
- 3.1.21 Straightness Test Method (see 8.5 and 9.6).

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 the electric-resistance-welded process and shall be made from hot- or cold-rolled steel as specified.

5. Chemical Composition

~~5.1 The steel shall conform to the requirements as to chemical composition prescribed in Tables 1 and~~
5.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1 or Table 2~~2~~. If no grade is specified, Grades MT 1010 to MT 1020 may be furnished. Analyses of steels other than those listed are available. To determine

TABLE 1 Chemical Requirements for Standard Low-Carbon Steels^A

NOTE 1— Chemistry represents heat analysis. Product analysis, except for rimmed or capped steel, is to be in accordance with usual practice as shown in Table 3.

Grade Designation	Chemical Composition Limits, %			
	Carbon	Manganese	Phosphorus, max	Sulfur, max
MT^B 1010	0.05–0.15	0.30–0.60	0.035	0.035
MT^B 1010	0.02–0.15	0.30–0.60	0.035	0.035
MT 1015	0.10–0.20	0.30–0.60	0.035	0.035
MT X 1015	0.10–0.20	0.60–0.90	0.035	0.035
MT 1020	0.15–0.25	0.30–0.60	0.035	0.035
MT X 1020	0.15–0.25	0.70–1.00	0.035	0.035

^A Rimmed or capped steels which may be used for the above grades are characterized by a lack of uniformity in their chemical composition, and for this reason product analysis is not technologically appropriate unless misapplication is clearly indicated.

^B The letters MT under grade designation indicate Mechanical Tubing.

TABLE 2 Chemical Requirements for Other Carbon and Alloy Steels^A

NOTE 1—Chemistry represents heat analysis. Product analysis, except for rimmed or capped steel, is to be in accordance with usual practice as shown in Table 3.

Grade Designation	Chemical Composition Limits, %							
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum
1008	0.10 max	0.50 max	0.035	0.035	...	...	...	...
1009	0.15 max	0.60 max	0.035	0.035	...	...	...	...
1010	0.08–0.13	0.30–0.60	0.035	0.035	...	...	...	...
1012	0.10–0.15	0.30–0.60	0.035	0.035	...	...	...	...
1015	0.12–0.18	0.30–0.60	0.035	0.035	...	...	...	...
1016	0.12–0.18	0.60–0.90	0.035	0.035	...	...	...	...
1017	0.14–0.20	0.30–0.60	0.035	0.035	...	...	...	...
1018	0.14–0.20	0.60–0.90	0.035	0.035	...	...	...	...
1019	0.14–0.20	0.70–1.00	0.035	0.035	...	...	...	...
1020	0.17–0.23	0.30–0.60	0.035	0.035	...	...	...	...
1021	0.17–0.23	0.60–0.90	0.035	0.035	...	...	...	...
1022	0.17–0.23	0.70–1.00	0.035	0.035	...	...	...	...
1023	0.19–0.25	0.30–0.60	0.035	0.035	...	...	...	...
1024	0.18–0.25	1.30–1.65	0.035	0.035	...	...	...	...
1025	0.22–0.28	0.30–0.60	0.035	0.035	...	...	...	...
1026	0.22–0.28	0.60–0.90	0.035	0.035	...	...	...	...
1027	0.22–0.29	1.20–1.55	0.035	0.035	...	...	...	...
1030	0.27–0.34	0.60–0.90	0.035	0.035	...	...	...	...
1033	0.29–0.36	0.70–1.00	0.035	0.035	...	...	...	...
1035	0.31–0.38	0.60–0.90	0.035	0.035	...	...	...	...
1040	0.36–0.44	0.60–0.90	0.040	0.050	...	...	...	...
1040	0.36–0.44	0.60–0.90	0.040	0.050	...	...	...	...
1050	0.47–0.55	0.60–0.90	0.040	0.050	...	...	...	...
1050	0.47–0.55	0.60–0.90	0.040	0.050	...	...	...	...
1060	0.55–0.66	0.60–0.90	0.040	0.050	...	...	...	...
1060	0.55–0.66	0.60–0.90	0.040	0.050	...	...	...	...
1340	0.38–0.43	1.60–1.90	0.035	0.040	0.15–0.35	...	...	...
1340	0.38–0.43	1.60–1.90	0.035	0.040	0.15–0.35	...	...	...
1524	0.18–0.25	1.35–1.65	0.040	0.050	...	...	...	...
1524	0.18–0.25	1.35–1.65	0.040	0.050	...	...	...	...
4118	0.18–0.23	0.70–0.90	0.035	0.040	0.15–0.35	...	0.40–0.60	0.08–0.15
4118	0.18–0.23	0.70–0.90	0.035	0.040	0.15–0.35	...	0.40–0.60	0.08–0.15
4130	0.28–0.33	0.40–0.60	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
4130	0.28–0.33	0.40–0.60	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
4140	0.38–0.43	0.75–1.00	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
4140	0.38–0.43	0.75–1.00	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
5130	0.23–0.33	0.70–0.90	0.035	0.040	0.15–0.35	...	0.80–1.10	...
5130	0.23–0.33	0.70–0.90	0.035	0.040	0.15–0.35	...	0.80–1.10	...
8620	0.18–0.23	0.70–0.90	0.035	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	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25

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

their availability, the purchaser should contact the producer.

5.2 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 Tables 1 and 2 is not permitted.

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 employed, 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 analysis shall be furnished to the purchaser.

7. Product Analysis

7.1 When requested on the purchase order, a product analysis shall be made by the supplier. The number and source of samples for such product analysis shall be based on the individual heat or lot identity of one of the following forms of material:

7.1.1 *Heat Identity Maintained*—One product analysis per heat shall be made on either the flat-rolled stock or tube.

7.1.2 *Heat Identity Not Maintained*—A product from one tube per 2000 ft (610 m) or less for sizes over 3 in. (76.2 mm), and one tube per 5000 ft (150 m) or less for sizes 3 in. and under.

7.2 Samples for product analysis except for spectrochemical analysis shall be taken in accordance with Practice E 1806. The composition thus determined shall correspond to the requirements of Tables 1-3.

7.3 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock 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 length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

8. Permissible Variations in Dimensions for Round Tubing

8.1 *Diameter and Wall Thickness (Hot-Rolled Steel)*—Variations from specified outside diameter for “as-welded” and “as-welded and annealed” tubing made from hot-rolled steel shall not exceed the amounts prescribed in Table 4. Permissible variations in outside diameter for tubing that has been sink-drawn for closer tolerance on outside diameter are shown in Table 5. Permissible variations in wall thickness for tubing that has been sink-drawn for closer tolerances on outside diameters are $\pm 10\%$ of the nominal wall or ± 0.010 in. (0.25 mm), whichever is greater. Permissible variations in wall thickness for tubing made from hot-rolled steel are shown in Table 6. Permissible variation in outside and inside diameter for tubing made from hot-rolled steel that has been mandrel drawn for closer tolerances are shown in Table 5 with wall tolerances shown in Table 7.

8.2 *Diameter and Wall Thickness (Cold-Rolled Steel)*—Variations in outside diameter and inside diameter of “as-welded” and “as-welded and annealed” tubing made from cold-rolled steel are shown in Table 8. Outside diameter tolerances for cold-rolled steel tubing, sink drawn and mandrel drawn, are shown in Table 5. Wall thickness tolerances for “as-welded” tubing made from cold-rolled steel are shown in Table 9. Permissible variations in wall thickness for round tubing, mandrel drawn for closer tolerances, are shown in Table 7. Permissible variations in wall thickness for tubing that has been sink-drawn for closer tolerances on outside diameter are $\pm 10\%$ of the nominal wall or ± 0.010 in. (0.25 mm), whichever is greater.

8.3 *Length (Hot- and Cold-Rolled Steel)*—Mechanical tubing is commonly furnished in mill lengths 5 ft (1.5 m) and over. Definite cut lengths are furnished when specified by the purchaser. Tolerances for definite cut lengths round tubing shall be as given in Tables 10 and 11.

8.4 *Squareness of Cut (Hot- and Cold-Rolled Steel)*—When specified, tolerance for squareness of cut of round tubing shall be as given in Table 12. Measurements are made with use of an “L” square and feeler gage. Side leg of square to be equal to tube diameter except minimum length of 1 in. (25.4 mm) and maximum length of 4 in. (101.6 mm). Outside diameter burr to be removed for measurement.

8.5 *Straightness*— The straightness tolerance for round tubing is 0.030 in./3 ft (0.76 mm/1 m) lengths to 8.000 in. (203 mm) outside diameter. For 8.000 in. outside diameter and above, straightness tolerance is 0.060 in./3 ft (1.52 mm/ 1 m) lengths. For lengths under 1 ft the straightness tolerance shall

8.6 *Ovality (Hot- and Cold-Rolled Steel)*—The ovality shall be within the tolerances except when the wall thickness is less than 3 % of the outside diameter.

8.6.1 In such cases for Types 1 and 2 (A.W.H.R. and A.W.C.R.) the ovality may be 50 % greater than the outside tolerances but the mean outside diameter shall be within the specified tolerance.

8.6.2 For Types 3, 4, 5, and 6 (S.D.H.R., S.D.C.R., M.D., and S.S.I.D.) the additional ovality shall be as follows but the mean outside diameter shall be within the specified tolerance:

TABLE 3 Tolerances for Product Analysis for Steels Shown in Tables 1 and 2^{A,B}

Element	Limit, or Maximum of Specified Range, %	Variation, Over the Maximum Limit or Under the Minimum Limit	
		Under min, %	Over max, %
Carbon	to 0.15, incl	0.02	0.03
	over 0.15 to 0.40, incl	0.03	0.04
	over 0.40 to 0.55, incl	0.03	0.05
Manganese	to 0.60, incl	0.03	0.03
	over 0.60 to 1.15, incl	0.04	0.04
	over 1.15 to 1.65, incl	0.05	0.05
Phosphorus		...	0.01
Sulfur		...	0.01
Silicon	to 0.30, incl	0.02	0.03
	over 0.30 to 0.60	0.05	0.05
Nickel	to 1.00, incl	0.03	0.03
Chromium	to 0.90, incl	0.03	0.03
	over 0.90 to 2.10, incl	0.05	0.05
Molybdenum	to 0.20, incl	0.01	0.01
	over 0.20 to 0.40, incl	0.02	0.02

^A 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.

^B Where the ellipsis (...) appears in this table, there is no requirement.

TABLE 4 Diameter Tolerances for Type I (A.W.H.R.) Round Tubing

 NOTE 1—Measurements for diameter are to be taken at least 2 in.^A from the ends of the tubes.

Outside Diameter Range, in. ^A	Wall Thickness		Flash-In-Tubing ^{B,C}	Flash Controlled to 0.010 in. max Tubing ^{C,D}	Flash Controlled to 0.005 in. max Tubing ^{E,D}	
	Bwg ^F	in. ^A	Outside Diameter, ±	Outside Diameter, ±	Outside Diameter, ±	Inside Diameter, ±
			Tolerances, in. ^{A,G}			
½ to 1⅛, incl	16 to 10	0.065 to 0.134	0.0035	0.0035	0.0035	0.020
Over 1⅛ to 2, incl	16 to 14	0.065 to 0.083	0.005	0.005	0.005	0.021
Over 1⅛ to 2, incl	13 to 7	0.095 to 0.180	0.005	0.005	0.005	0.025
Over 1⅛ to 2, incl	6 to 5	0.203 to 0.220	0.005	0.005	0.005	0.029
Over 1⅛ to 2, incl	4 to 3	0.238 to 0.259	0.005	0.005	0.005	0.039
Over 2 to 2½, incl	16 to 14	0.065 to 0.083	0.006	0.006	0.006	0.022
Over 2 to 2½, incl	13 to 5	0.095 to 0.220	0.006	0.006	0.006	0.024
Over 2 to 2½, incl	4 to 3	0.238 to 0.259	0.006	0.006	0.006	0.040
Over 2½ to 3, incl	16 to 14	0.065 to 0.083	0.008	0.008	0.008	0.024
Over 2½ to 3, incl	13 to 5	0.095 to 0.220	0.008	0.008	0.008	0.026
Over 2½ to 3, incl	4 to 3	0.238 to 0.259	0.008	0.008	0.008	0.040
Over 2½ to 3, incl	2 to 0.320	0.284 to 0.320	0.010	0.010	0.010	0.048
Over 3 to 3½, incl	16 to 14	0.065 to 0.083	0.009	0.009	0.009	0.025
Over 3 to 3½, incl	13 to 5	0.095 to 0.220	0.009	0.009	0.009	0.027
Over 3 to 3½, incl	4 to 3	0.238 to 0.259	0.009	0.009	0.009	0.043
Over 3 to 3½, incl	2 to 0.360	0.284 to 0.360	0.012	0.012	0.012	0.050
Over 3½ to 4, incl	16 to 14	0.065 to 0.083	0.010	0.010	0.010	0.026
Over 3½ to 4, incl	13 to 5	0.095 to 0.220	0.010	0.010	0.010	0.028
Over 3½ to 4, incl	4 to 3	0.238 to 0.259	0.010	0.010	0.010	0.044
Over 3½ to 4, incl	2 to 0.500	0.284 to 0.500	0.015	0.015	0.015	0.053
Over 4 to 5, incl	16 to 14	0.065 to 0.083	0.020	0.020	0.020	0.036
Over 4 to 5, incl	13 to 5	0.095 to 0.220	0.020	0.020	0.020	0.045
Over 4 to 5, incl	4 to 3	0.238 to 0.259	0.020	0.020	0.020	0.054
Over 4 to 5, incl	2 to 0.500	0.284 to 0.500	0.020	0.020	0.020	0.058
Over 5 to 6, incl	16 to 10	0.065 to 0.134	0.020	0.020	0.020	0.036
Over 5 to 6, incl	9 to 5	0.148 to 0.220	0.020	0.020	0.020	0.040
Over 5 to 6, incl	4 to 3	0.238 to 0.259	0.020	0.020	0.020	0.054
Over 5 to 6, incl	2 to 0.500	0.284 to 0.500	0.020	0.020	0.020	0.058
Over 6 to 8, incl	11 to 10	0.120 to 0.134	0.025	0.025	0.025	0.043
Over 6 to 8, incl	9 to 5	0.148 to 0.220	0.025	0.025	0.025	0.045
Over 6 to 8, incl	4 to 3	0.238 to 0.259	0.025	0.025	0.025	0.059
Over 6 to 8, incl	2 to 0.500	0.284 to 0.500	0.025	0.025	0.025	0.063
Over 8 to 10, incl	14 to 12	0.083 to 0.109	0.030	0.030	0.030	0.041
Over 8 to 10, incl	11 to 10	0.120 to 0.134	0.030	0.030	0.030	0.043
Over 8 to 10, incl	9 to 5	0.148 to 0.220	0.030	0.030	0.030	0.045
Over 8 to 10, incl	4 to 3	0.238 to 0.259	0.030	0.030	0.030	0.059
Over 8 to 10, incl	2 to 0.500	0.248 to 0.500	0.030	0.030	0.030	0.063
Over 10 to 12, incl	14 to 12	0.083 to 0.109	0.035	0.035	0.035	0.041
Over 10 to 12, incl	11 to 10	0.120 to 0.134	0.035	0.035	0.035	0.043
Over 10 to 12, incl	9 to 5	0.148 to 0.220	0.035	0.035	0.035	0.045
Over 10 to 12, incl	4 to 3	0.238 to 0.259	0.035	0.035	0.035	0.059
Over 10 to 12, incl	2 to 0.500	0.284 to 0.500	0.035	0.035	0.035	0.063

^A 1 in. = 25.4 mm.

^B Flash-In-Tubing is produced only to outside diameter tolerances and wall thickness tolerances and the inside diameter welding flash does not exceed the wall thickness or ⅜ in., whichever is less.

^C Flash Controlled to 0.010 in. maximum tubing consists of tubing which is commonly produced only to outside diameter tolerances and wall thickness tolerances, in which the height of the remaining welding flash is controlled not to exceed 0.010 in.

^D No Flash tubing is further processed for closer tolerances with mandrel-tubing produced to outside diameter and wall, inside diameter and wall, or outside diameter and inside diameter to tolerances with no dimensional indication of inside diameter flash. This condition is available in Types 5 and 6.

^E Flash Controlled to 0.005 in. maximum tubing is produced to outside diameters and wall thickness tolerance, inside diameter and wall thickness tolerances, or outside diameters and inside diameter tolerances, in which the height of the remaining flash is controlled not to exceed 0.005 in. Any remaining flash is considered to be part of the applicable inside diameter tolerances.

^F Birmingham Wire Gage.

^G The ovality shall be within the above tolerances except when the wall thickness is less than 3 % of the outside diameter, in such cases see 8.6.1.

TABLE 5 Diameter Tolerances for Types 3, 4, 5, and 6 (S.D.H.R., S.D.C.R., M.D. and S.S.I.D) Round Tubing

NOTE 1—Measurements for diameter are to be taken at least 2 in. from the ends of the tubes.

OD Size Range ^A	Wall % of OD	Types 3, 4, (Sink Drawn) ^{A,B} and 5, 6, (Mandrel Drawn) ^{B,C} OD, in.		Types 5 and 6 (Mandrel Drawn) ^{B,C,D} ID in.	
		Over	Under	Over	Under
Up to 0.499	all	0.004	0.000	...	...
0.500 to 1.699	all	0.005	0.000	0.000	0.005
1.700 to 2.099	all	0.006	0.000	0.000	0.006
2.100 to 2.499	all	0.007	0.000	0.000	0.007
2.500 to 2.899	all	0.008	0.000	0.000	0.008
2.900 to 3.299	all	0.009	0.000	0.000	0.009
3.300 to 3.699	all	0.010	0.000	0.000	0.010
3.700 to 4.099	all	0.011	0.000	0.000	0.011
4.100 to 4.499	all	0.012	0.000	0.000	0.012
4.500 to 4.899	all	0.013	0.000	0.000	0.013
4.900 to 5.299	all	0.014	0.000	0.000	0.014
5.300 to 5.549	all	0.015	0.000	0.000	0.015
5.550 to 5.999	under 6	0.010	0.010	0.010	0.010
	6 and over	0.009	0.009	0.009	0.009
6.000 to 6.499	under 6	0.013	0.013	0.013	0.013
	6 and over	0.010	0.010	0.010	0.010
6.500 to 6.999	under 6	0.015	0.015	0.015	0.015
	6 and over	0.012	0.012	0.012	0.012
7.000 to 7.499	under 6	0.018	0.018	0.018	0.018
	6 and over	0.013	0.013	0.013	0.013
7.500 to 7.999	under 6	0.020	0.020	0.020	0.020
	6 and over	0.015	0.015	0.015	0.015
8.000 to 8.499	under 6	0.023	0.023	0.023	0.023
	6 and over	0.016	0.016	0.016	0.016
8.500 to 8.999	under 6	0.025	0.025	0.025	0.025
	6 and over	0.017	0.017	0.017	0.017
9.000 to 9.499	under 6	0.028	0.028	0.028	0.028
	6 and over	0.019	0.019	0.019	0.019
9.500 to 9.999	under 6	0.030	0.030	0.030	0.030
	6 and over	0.020	0.020	0.020	0.020
10.000 to 10.999	all	0.034	0.034	0.034	0.034
11.000 to 11.999	all	0.035	0.035	0.035	0.035
12.000 to 12.999	all	0.036	0.036	0.036	0.036
13.000 to 13.999	all	0.037	0.037	0.037	0.037
14.000 to 14.999	all	0.038	0.038	0.038	0.038

^A Tubing, flash in or flash controlled which is further processed without mandrel to obtain tolerances closer than those shown in Tables 4 and 8.

^B The ovality shall be within the above tolerances except when the wall thickness is less than 3 % of the outside diameter, in such cases see 8.6.2.

^C Tubing produced to outside diameter and wall thickness, or inside diameter and wall thickness, or outside diameter and inside diameter, with mandrel to obtain tolerances closer than those shown in Tables 4 and 8 and no dimensional indication of inside diameter flash.

^D Where the ellipsis (...) appears in this table, the tolerance is not addressed.

Outside Diameter, in. (mm)	Additional Ovality Tolerance, in. (mm)
Up to 2 (50.8), incl	0.010 (0.25)
Over 2 to 3 (50.8 to 76.2), incl	0.015 (0.38)
Over 3 to 4 (76.2 to 101.6), incl	0.020 (0.51)
Over 4 to 5 (101.6 to 127.0), incl	0.025 (0.64)
Over 5 to 6 (127.0 to 152.4), incl	0.030 (0.76)
Over 6 to 7 (152.4 to 177.8), incl	0.035 (0.89)
Over 7 to 8 (177.8 to 203.2), incl	0.040 (1.02)
Over 8 to 9 (203.2 to 228.6), incl	0.045 (1.14)
Over 9 to 10 (228.6 to 254.0), incl	0.050 (1.27)
Over 10 to 11 (254.0 to 279.4), incl	0.055 (1.40)
Over 11 to 12 (279.4 to 304.8), incl	0.060 (1.52)
Over 12 to 12.500 (304.8 to 317.5), incl	0.065 (1.65)

9. Permissible Variations in Dimensions of Square and Rectangular Tubing

9.1 *Diameter and Wall Thickness*—Permissible variations in outside dimensions for square and rectangular tubing shall be as given in Table 13. The wall thickness tolerance is $\pm 10\%$ of the nominal wall thickness.

9.2 *Corner Radii*—Unless otherwise specified, the corners of square and rectangular tubing shall be slightly rounded inside and

TABLE 6 Wall Thickness Tolerance for Type I (A.W.H.R.) Round Tubing

in. ^A	Outside Diameter, in. ^A															
	3/4 to 1, incl		Over 1 to 1 1/16, incl		Over 1 1/16 to 3 3/4, incl		Over 3 3/4 to 4 1/2, incl		Over 4 1/2 to 6, incl		Over 6 to 8, incl		Over 8 to 10, incl		Over 10 to 12, incl	
	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
0.065	0.005	0.009	0.004	0.010	0.003	0.011	0.002	0.012	0.002	0.012	0.002	0.012	0.002	0.012	0.002	0.012
0.072	0.005	0.009	0.004	0.010	0.003	0.011	0.002	0.012	0.002	0.012	0.002	0.012	0.002	0.012	0.002	0.012
0.083	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.095	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.109	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.120	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.134	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.148	...	...	0.006	0.012	0.005	0.013	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014
0.165	...	...	0.006	0.012	0.005	0.013	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014
0.180	...	...	0.006	0.012	0.005	0.013	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014
0.203	...	...	...	...	0.007	0.015	0.006	0.016	0.005	0.017	0.005	0.017	0.005	0.017	0.005	0.017
0.220	...	...	...	...	0.007	0.015	0.006	0.016	0.005	0.017	0.005	0.017	0.005	0.017	0.005	0.017
0.238	...	...	...	...	0.012	0.020	0.011	0.021	0.010	0.022	0.010	0.022	0.010	0.022	0.010	0.022
0.259	...	...	...	...	0.013	0.021	0.012	0.022	0.011	0.023	0.011	0.023	0.011	0.023	0.011	0.023
0.284	...	...	...	...	0.014	0.022	0.013	0.023	0.012	0.024	0.012	0.024	0.012	0.024	0.012	0.024
0.300	...	...	...	...	0.015	0.023	0.014	0.024	0.013	0.025	0.013	0.025	0.013	0.025	0.013	0.025
0.320	...	...	...	...	0.016	0.024	0.015	0.025	0.014	0.026	0.014	0.026	0.014	0.026	0.014	0.026
0.344	...	...	...	...	0.017	0.025	0.016	0.026	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027
0.360	...	...	...	...	0.017	0.025	0.016	0.026	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027
0.375	...	...	...	...	...	...	0.016	0.026	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027
0.406	...	...	...	...	...	...	0.017	0.027	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028
0.438	...	...	...	...	...	...	0.017	0.027	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028
0.469	...	...	...	...	...	...	...	...	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028
0.500	...	...	...	...	...	...	...	...	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028

^A 1 in. = 25.4 mm.

^B Birmingham Wire Gage.

^C Where the ellipsis (...) appears in this table, the tolerance is not addressed.

TABLE 7 Wall Thickness Tolerances of Types 5 and 6 (M.D. and S.S.I.D.) Round Tubing

		Outside Diameter, in. ^A							
Wall Thickness		3/8 to 7/8 , incl		Over 7/8 to 1 7/8 , incl		Over 1 7/8 to 3 3/4 , incl		Over 3 3/4 to 15, incl	
in. ^A	Bwg ^B	Wall Thickness Tolerances, in., ^{A,C} ±							
		+	-	+	-	+	-	+	-
0.035	20	0.002	0.002	0.002	0.002	0.002	0.002	...	...
0.049	18	0.002	0.002	0.002	0.003	0.002	0.003	...	...
0.065	16	0.002	0.002	0.002	0.003	0.002	0.003	0.004	0.004
0.083	14	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.005
0.095	13	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.005
0.109	12	0.002	0.003	0.002	0.004	0.003	0.003	0.005	0.005
0.120	11	0.003	0.003	0.002	0.004	0.003	0.003	0.005	0.005
0.134	10	...	...	0.002	0.004	0.003	0.003	0.005	0.005
0.148	9	...	...	0.002	0.004	0.003	0.003	0.005	0.005
0.165	8	...	...	0.003	0.004	0.003	0.004	0.005	0.006
0.180	7	...	...	0.004	0.004	0.003	0.005	0.006	0.006
0.203	6	...	...	0.004	0.005	0.004	0.005	0.006	0.007
0.220	5	...	...	0.004	0.006	0.004	0.006	0.007	0.007
0.238	4	...	...	0.005	0.006	0.005	0.006	0.007	0.007
0.259	3	...	...	0.005	0.006	0.005	0.006	0.007	0.007
0.284	2	...	...	0.005	0.006	0.005	0.006	0.007	0.007
0.300	1	...	...	0.006	0.006	0.006	0.006	0.008	0.008
0.320	...	...	...	0.007	0.007	0.007	0.007	0.008	0.008
0.344	...	...	...	0.008	0.008	0.008	0.008	0.009	0.009
0.375	...	...	...	...	...	0.009	0.009	0.009	0.009
0.400	...	...	...	...	...	0.010	0.010	0.010	0.010
0.438	...	...	...	...	...	0.011	0.011	0.011	0.011
0.460	...	...	...	...	...	0.012	0.012	0.012	0.012
0.480	...	...	...	...	...	0.012	0.012	0.012	0.012
0.531	...	...	...	...	...	0.013	0.013	0.013	0.013
0.563	...	...	...	...	...	0.013	0.013	0.013	0.013
0.580	...	...	...	...	...	0.014	0.014	0.014	0.014
0.600	...	...	...	...	...	0.015	0.015	0.015	0.015
0.625	...	...	...	...	...	0.016	0.016	0.016	0.016
0.650	...	...	...	...	0.017	0.017	0.017	0.017	0.017

^A 1 in. = 25.4 mm.
^B Birmingham Wire Gage.
^C Where the ellipsis (...) appears in this table, the tolerance is not addressed.

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outside, consistent with wall thickness. The outside corners may be slightly flattened. The radii of corners shall be as given in Table 14.

9.3 *Squareness*—Permissible variations for squareness shall be determined by the following equation:

$$\pm b = c \times 0.006 \text{ in.}$$

where:

- b* = tolerance for out-of-square, and
- c* = largest external dimension across flats.

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

9.3.1 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 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.

9.4 *Length*—Variations from the specified length shall not exceed the amount prescribed in Table 15.

9.5 *Twist*—Twist tolerances are shown in Table 16. 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 of either corner of the opposite end of same side above the surface plate. 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.

9.6 *Straightness*— The straightness tolerance is 1/16 in./3 ft (1.7 mm/1 m). The test method for straightness measurement is at the manufacturer’s option, unless a specific test method is specified in the purchase order.

10. Tubing Sections Other Than Square and Rectangular

10.1 In addition to square and rectangular tubing, many producers supply a variety of special sections, such as oval, streamlined, hexagonal, octagonal, round inside and hexagonal or octagonal outside, ribbed inside or out, triangular, rounded rectangular and D shapes. Manufacturing practices limit the size range and section available from the various producers. These special sections

TABLE 8 Diameter Tolerances for Type 2 (A.W.C.R.) Round Tubing

 NOTE 1—Measurements for diameter are to be taken at least 2 in. from the ends of the tubes.^A

Outside Diameter Range, in. ^A	Wall Thickness		Flash-in-Tubing ^B	Flash Controlled to 0.010 in. max Tubing ^C	Flash Controlled ^D to 0.005 in. max Tubing	
	Bwg ^A	in. ^E			Outside Diameter, ±	Outside Diameter, ±
			Tolerances, in. ^{F,G}			
3/8 to 5/8, incl	24 to 16	0.022 to 0.065	0.003	...	...	...
Over 5/8 to 1 1/8, incl	24 to 19	0.022 to 0.042	0.0035	0.0035	0.0035	0.013
Over 5/8 to 1 1/8, incl	18	0.049	0.0035	0.0035	0.0035	0.015
Over 5/8 to 1 1/8, incl	16 to 14	0.065 to 0.083	0.0035	0.0035	0.0035	0.019
Over 3/4 to 1 1/8, incl	13	0.095	0.0035	0.0035	0.0035	0.019
Over 7/8 to 1 1/8, incl	12 to 11	0.109 to 0.120	0.0035	0.0035	0.0035	0.021
Over 1 1/8 to 2, incl	22 to 18	0.028 to 0.049	0.005	0.005	0.005	0.015
Over 1 1/8 to 2, incl	16 to 13	0.065 to 0.095	0.005	0.005	0.005	0.019
Over 1 1/8 to 2, incl	12 to 10	0.109 to 0.134	0.005	0.005	0.005	0.022
Over 2 to 2 1/2, incl	20 to 18	0.035 to 0.049	0.006	0.006	0.006	0.016
Over 2 to 2 1/2, incl	16 to 13	0.065 to 0.095	0.006	0.006	0.006	0.020
Over 2 to 2 1/2, incl	12 to 10	0.109 to 0.134	0.006	0.006	0.006	0.023
Over 2 1/2 to 3, incl	20 to 18	0.035 to 0.049	0.008	0.008	0.008	0.018
Over 2 1/2 to 3, incl	16 to 13	0.065 to 0.095	0.008	0.008	0.008	0.022
Over 2 1/2 to 3, incl	12 to 10	0.109 to 0.134	0.008	0.008	0.008	0.025
Over 3 to 3 1/2, incl	20 to 18	0.035 to 0.049	0.009	0.009	0.009	0.019
Over 3 to 3 1/2, incl	16 to 13	0.065 to 0.095	0.009	0.009	0.009	0.023
Over 3 to 3 1/2, incl	12 to 10	0.109 to 0.134	0.009	0.009	0.009	0.026
Over 3 1/2 to 4, incl	20 to 18	0.035 to 0.049	0.010	0.010	0.010	0.020
Over 3 1/2 to 4, incl	16 to 13	0.065 to 0.095	0.010	0.010	0.010	0.024
Over 3 1/2 to 4, incl	12 to 10	0.109 to 0.134	0.010	0.010	0.010	0.027
Over 4 to 6, incl	16 to 13	0.065 to 0.095	0.020	0.020	0.020	0.034
Over 4 to 6, incl	12 to 10	0.109 to 0.134	0.020	0.020	0.020	0.037
Over 6 to 8, incl	14 to 13	0.083 to 0.095	0.025	0.025	0.025	0.039
Over 6 to 8, incl	12 to 10	0.109 to 0.134	0.025	0.025	0.025	0.042
Over 8 to 10, incl	16 to 13	0.065 to 0.095	0.030	0.030	0.030	0.044
Over 8 to 10, incl	12 to 10	1.109 to 0.134	0.030	0.030	0.030	0.049
Over 10 to 12, incl	14 to 13	0.083 to 0.095	0.035	0.035	0.035	0.049
Over 10 to 12, incl	12 to 10	0.109 to 0.134	0.035	0.035	0.035	0.054

^A 1 in. = 25.4 mm.

^B Flash-In-Tubing is produced to outside diameter tolerances and wall thickness tolerances only, and the height of the inside welding flash does not exceed the wall thickness or 3/32 in., whichever is less.

^C Flash Controlled to 0.010 in. maximum tubing consists of tubing over 5/8 in. outside diameter which is commonly produced to outside diameter tolerances and wall thickness tolerances only, in which the height of the remaining inside welding flash is controlled not to exceed 0.010 in.

^D Flash Controlled to 0.005 in. maximum tubing is produced to outside diameter tolerances and wall thickness tolerances, inside diameter tolerances and wall thickness tolerances, or outside diameter tolerances and inside diameter tolerances, in which the height of the remaining inside welding flash is controlled not to exceed 0.005 in. Any remaining flash is considered to be part of the applicable inside diameter tolerances.

^E Birmingham Wire Gage.

^F The ovality shall be within the above tolerances except when the wall thickness is less than 3 % of the outside diameter, in such cases see 8.6.1.

^G Where the ellipsis (...) appears in this table, the tolerance is not addressed.

may be made through turkshead rolls or through a die with or without use of a mandrel. Since the sections are special, dies and other tools are not held available. Therefore, when inquiring for shapes other than square and rectangular, it is essential to give full details as to dimensions and finish.

11. Workmanship, Finish, and Appearance

11.1 The tubing shall be free of injurious defects and shall have a workmanlike finish.

11.2 Unless otherwise specified in the purchase order, the tubing shall be free of scale. In the case of thermally treated tubing a slight amount of color will not be considered cause for rejection.

11.3 When burrs must be removed from one or both ends, it shall be specified in the purchase order.

TABLE 9 Wall Thickness Tolerances for Type 2 (A.W.C.R.) Round Tubing

Wall Thickness in. ^A	Outside Diameter, in. ^A															
	3/8 to 7/8, incl		Over 7/8 to 1 1/8, incl		Over 1 1/8 to 3 3/4, incl		Over 1 7/8 to 3 3/4, incl		Over 3 3/4 to 5, incl		Over 6 to 8, incl		Over 8 to 10, incl		Over 10 to 12, incl	
Bwg ^B	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
0.022	0.001	0.005	0.001	0.005	...	...	...	...	...	...	...	...	...	...	...	...
0.028	0.001	0.005	0.001	0.005	...	...	...	...	...	...	...	...	...	...	...	...
0.035	0.002	0.005	0.001	0.005	0.001	0.005	...	...	...	...	...	...	...	...	...	...
0.042	0.002	0.006	0.001	0.006	0.001	0.006	...	...	...	...	...	...	...	...	...	...
0.049	0.003	0.006	0.002	0.006	0.002	0.006	...	...	...	...	...	...	...	...	...	...
0.065	0.005	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007
0.083	0.006	0.007	0.005	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007
0.095	0.006	0.007	0.005	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007
0.109	...	...	0.006	0.008	0.005	0.008	0.005	0.008	0.005	0.008	0.005	0.008	0.005	0.008	0.005	0.008
0.120	...	...	0.007	0.008	0.006	0.008	0.005	0.008	0.005	0.008	0.005	0.008	0.005	0.008	0.005	0.008
0.134	...	...	0.007	0.008	0.006	0.008	0.005	0.008	0.005	0.008	0.005	0.008	0.005	0.008	0.005	0.008

^A 1 in. = 25.4 mm.

^B Birmingham Wire Gage.

^C Where the ellipsis appears in this table, the tolerance is not addressed.