Designation: A 1016/A 1016M – 04

Standard Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes[1]

This standard is issued under the fixed designation A 1016/A 1016M; 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.

1. Scope*

1.1 This specification covers a group of requirements that, unless otherwise specified in an individual specification, shall apply to the ASTM product specifications noted below.

Title of Specification	ASTM Designation[A]
Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes	A 209/A 209M
Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes	A 213/A 213M
Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes	A 249/A 249M
Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes	A 250/A 250M
Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service	A 268/A 268M
Seamless and Welded Austenitic Stainless Steel Tubing for General Service	A 269
Seamless and Welded Austenitic Stainless Steel Sanitary Tubing	A 270
Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service	A 334/A 334M
Welded Austenitic Stainless Steel Feedwater Heater Tubes	A 688/A 688M
Austenitic Stainless Steel Tubing for Breeder Reactor Core Components	A 771/A 771M
Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service	A 789/A 789M
Welded Ferritic Stainless Steel Feedwater Heater Tubes	A 803/A 803M
Austenitic and Ferritic Stainless Steel Duct Tubes for Breeder Reactor Core Components	A 826
High-Frequency Induction Welded, Unannealed Austenitic Steel Condenser Tubes	A 851

[A] These designations refer to the latest issue of the respective specifications.

1.2 In the case of conflict between a requirement of a product specification and a requirement of this general requirements specification, the product specification shall prevail. In the case of conflict between a requirement of the product specification or a requirement of this general requirements specification and a more stringent requirement of the purchase order, the purchase order shall prevail.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation (SI) of the product specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 209/A 209M Specification for Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes

A 213/A 213M Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes

A 249/A 249M Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes

A 250/A 250M Specification for Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes

A 268/A 268M Specification for Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service

A 269 Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

A 270 Specification for Seamless and Welded Austenitic Stainless Steel Sanitary Tubing

A 334/A 334M Specification for Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service

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

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 668/A 668M Specification for Welded Austenitic Stainless Steel Feedwater Heater Tubes

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.10 on Stainless and Alloy Steel Tubular Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

A 771/A 771M Specification for Seamless Austenitic and Martensitic Stainless Steel Tubing for Liquid Metal-Cooled Reactor Core Components
A 789/A 789M Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service
A 803/A 803M Specification for Welded Ferritic Stainless Steel Feedwater Heater Tubes
A 826 Specification for Seamless Austenitic and Martensitic Stainless Steel Duct Tubes for Liquid Metal-Cooled Reactor Core Components[3]
A 851 Specification for High-Frequency Induction Welded, Unannealed Austenitic Steel Condenser Tubes[3]
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
D 3951 Practice for Commercial Packaging
E 92 Test Method for Vickers Hardness of Metallic Materials
E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
E 273 Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing
E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation
E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys
E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *ASME Boiler and Pressure Vessel Code:*
Section IX, Welding Qualifications[4]

2.3 *Federal Standard:*
Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products[5]

2.4 *Military Standards:*
MIL-STD-271 Nondestructive Testing Requirements for Metals[5]
MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[5]
MIL-STD-792 Identification Marking Requirements for Special Purpose Equipment[5]

2.5 *Steel Structures Painting Council:*
SSPC-SP6 Surface Preparation Specification No.6 Commercial Blast Cleaning[6]

2.6 *Other Documents:*
SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification[7]
AIAG Bar Code Symbology Standard[8]

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[3] Withdrawn.
[4] Available from the ASME International Headquarters, Three Park Ave., New York, NY 10016–5990.
[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, Attn: NPODS.
[6] Available from Steel Structures Painting Council, 40 24th St., 6th Floor, Pittsburgh, PA 15222–4656.
[7] Available from American Society for Nondestructive Testing, P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228–0518.
[8] Available from Automotive Industry Action Group, 26200 Lahser Rd., Suite 200, Southfield, MI 48034.

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Test Methods and Definitions A 370, Test Methods, Practices, and Terminology A 751, and Terminology A 941 are applicable to this specification and to those listed in 1.1.

3.1.2 *heat*, *n*—in secondary melting, all of the ingots remelted from a single primary heat.

3.1.3 *imperfection*, *n*—any discontinuity or irregularity found in a tube.

4. Manufacture

4.1 The steel shall made by any process.

4.2 The primary melting is permitted to incorporate separate degassing or refining and is permitted to be followed by secondary melting, such as electroslag remelting or vacuum-arc remelting.

4.3 When steel of different grades is sequentially strand cast, the resultant transition material shall be removed using an established procedure that positively separates the grades.

5. Ordering Information

5.1 It is the responsibility of the purchaser to specify all requirements that are necessary for product ordered under the product specification. Such requirements to be considered include, but are not limited to, the following:

5.1.1 Quantity (feet, metres, or number of pieces),

5.1.2 Name of material (stainless steel tubing),

5.1.3 Method of manufacture, when applicable (seamless (SML), welded (WLD), or heavily cold-worked (HCW)),

5.1.4 Grade or UNS number,

5.1.5 Size (outside diameter and average or minimum wall thickness),

5.1.6 Length (specific or random),

5.1.7 End finish if required,

5.1.8 Optional requirements,

5.1.9 Specific type of melting, if required,

5.1.10 Test report requirements,

5.1.11 Specification designation and year of issue, and

5.1.12 Special requirements or any supplementary requirements, or both.

6. Chemical Composition

6.1 *Chemical Analysis*—Samples for chemical analysis, and method of analysis, shall be in accordance with Test Methods, Practices, and Terminology A 751.

6.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall conform to the requirements specified in the product specification.

6.3 *Product Analysis*—Product analysis requirements and options, if any, shall be as contained in the product specification.

7. Tensile Properties

7.1 The material shall conform to the tensile property requirements prescribed in the individual product specification.

7.2 The yield strength, when specified, shall be determined corresponding to a permanent offset of 0.2 % of the gage length or to a total extension of 0.5 % of the gage length under load.

7.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than ¾ in. [19.0 mm] from the center of the gage length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

8. Standard Mass per Unit Length

8.1 The calculated mass per foot, based upon a specified minimum wall thickness, shall be determined by the following equation (see Note 1):

$$W = C(D–t)t \quad (1)$$

where:
C = 10.69 [0.0246615],
W = mass per unit length, lb/ft [kg/m],
D = specified outside diameter, in. [mm], and
t = specified minimum wall thickness, in. [mm].

NOTE 1—The calculated masses given by Eq 1 are based on the masses for carbon steel tubing. The mass of tubing made of ferritic stainless steels may be up to about 5 % less, and that made of austenitic stainless steel up to about 2 % greater than the values given. Mass of ferritic/austenitic (duplex) stainless steel will be intermediate to the mass of fully austenitic and fully ferritic stainless steel tubing.

8.2 The permitted variations from the calculated mass per foot [kilogram per meter] shall be as prescribed in Table 1.

9. Permitted Variations in Wall Thickness

9.1 Variations from the specified minimum wall thickness shall not exceed the amounts prescribed in Table 2.

9.2 For tubes 2 in. [50 mm] and over in outside diameter and 0.220 in. [5.6 mm] and over in thickness, the variation in wall thickness in any one cross section of any one tube shall not exceed the following percentage of the actual mean wall at the section. The actual mean wall is defined as the average of the thickest and thinnest wall in that section.

Seamless tubes ±10 %
Welded tubes ±5 %

9.3 When cold-finished tubes as ordered require wall thicknesses ¾ in. [19.1 mm] or over, or an inside diameter 60 % or less of the outside diameter, the permitted variations in wall thickness for hot-finished tubes shall apply.

TABLE 1 Permitted Variations in Mass Per Foot[A]

Method of Manufacture	Permitted Variation in Mass per Foot, %	
	Over	Under
Seamless, hot-finished	16	0
Seamless, cold-finished		
1½ in. [38 mm] and under OD	12	0
Over 1½ in. [38 mm] OD	13	0
Welded	10	0

[A] These permitted variations in mass apply to lots of 50 tubes or more in sizes 4 in. [101.6 mm] and under in outside diameter, and to lots of 20 tubes or more in sizes over 4 in. [101.6 mm] in outside diameter.

TABLE 2 Permitted Variations in Wall Thickness[A]

Outside Diameter in. [mm]	Wall Thickness, %							
	0.095 [2.4] and Under		Over 0.095 to 0.150 [2.4 to 3.8], incl		Over 0.150 to 0.0180 [3.8 to 4.6], incl		Over 0.180 [4.6]	
	Over	Under	Over	Under	Over	Under	Over	Under
Seamless, Hot-Finished Tubes								
4 [100] and under	40	0	35	0	33	0	28	0
Over 4 [100]	. . .	. . .	35	0	33	0	28	0
Seamless, Cold-Finished Tubes								
			Over	Under				
1½ [38.1] and under			20	0				
Over 1½ [38.1]			22	0				
Welded Tubes								
All sizes			18	0				

[A] These permitted variations in wall thickness apply only to tubes, except internal-upset tubes, as rolled or cold-finished, and before swaging, expanding, bending, polishing, or other fabricating operations.

10. Permitted Variations in Outside Diameter

10.1 Except as provided in 10.2.1, 10.3, and 25.10.4, variations from the specified outside diameter shall not exceed the amounts prescribed in Table 3.

10.2 Thin-wall tubes usually develop significant ovality (out-of-roundness) during final annealing, or straightening, or both. Thin-wall tubes are defined as those with a specified wall 3 % or less than the specified OD, or with a wall specified as 0.020 in. [0.5 mm] or less.

10.2.1 1 The diameter tolerances of Table 3 are not sufficient to provide for additional ovality expected in thin-wall tubes, and, for such tubes, are applicable only to the mean of the extreme (maximum and minimum) outside diameter readings in any one cross section. However, for thin wall tubes the difference in extreme outside diameter readings (ovality) in any one cross section shall not exceed the following ovality allowances:

TABLE 3 Permitted Variations in Outside Diameter[A]

Specified Outside Diameter, in. [mm]	Permitted Variations, in. [mm] Over	Under
Hot-Finished Seamless Tubes		
4 [100] or under	1⁄64 [0.4]	1⁄32 [0.8]
Over 4 to 7½ [100 to 200], incl	1⁄64 [0.4]	3⁄64 [1.2]
Over 7½ to 9 [200 to 225], incl	1⁄64 [0.4]	1⁄16 [1.6]
Welded Tubes and Cold-Finished Seamless Tubes		
Under 1 [25]	0.004 [0.1]	0.004 [0.11]
1 to 1½ [25 to 40], incl	0.006 [0.15]	0.006 [0.15]
Over 1½ to 2 [40 to 50], excl	0.008 [0.2]	0.008 [0.2]
2 to 2½ [50 to 65], excl	0.010 [0.25]	0.010 [0.25]
2½ to 3 [65 to 75], excl	0.012 [0.3]	0.012 [0.3]
3 to 4 [75 to 100], incl	0.015 [0.38]	0.015 [0.38]
Over 4 to 7½ [100 to 200], incl	0.015 [0.38]	0.025 [0.64]
Over 7½ to 9 [200 to 225], incl	0.015 [0.38]	0.045 [1.14]

[A] Except as provided in 10.2 and 10.3, these permitted variations include out-of-roundness. These permitted variations in outside diameter apply to hot-finished seamless, welded and cold-finished seamless tubes before other fabricating operations such as upsetting, swaging, expanding, bending, or polishing.

Outside Diameter, in. [mm]	Ovality Allowance
1 [25.4] and under	0.020 [0.5]
Over 1 [25.4]	2.0 % of specified outside diameter

10.3 For cold-finished seamless austenitic and ferritic/austenitic tubes, an ovality allowance is necessary for all sizes less than 2 in. [50.8 mm] outside diameter, because they are likely to become out of round during their final heat treatment. For such tubes, the maximum and minimum outside diameter at any cross section shall not deviate from the nominal diameter by more than ±0.010 in. [±0.25 mm]. However, the mean diameter at that cross section must still be within the given permitted variation given in Table 3. In the event of conflict between the provisions of 10.2.1 and those of 10.3, the larger value of ovality tolerance shall apply.

10.4 When the specified wall is 2 % or less of the specified OD, the method of measurement is per agreement between purchaser and manufacturer (see Note 2).

NOTE 2—Very thin wall tubing may not be stiff enough for the outside diameter to be accurately measured with a point contact method, such as with the use of a micrometer or caliper. When very thin walls are specified, "go" – "no go" ring gages are commonly used to measure diameters of 1½ in. [38.1 mm] or less. A .002 in. [0.05 mm] additional tolerance is usually added on the "go" ring gage to allow clearance for sliding. On larger diameters, measurement is commonly performed with a pi tape. Other methods, such as optical methods, may also be considered.

11. Permitted Variations in Length

11.1 Variations from the specified length shall not exceed the amounts prescribed in Table 4.

12. Permitted Variations in Height of Flash on Electric-Resistance-Welded Tubes

12.1 For tubes over 2 in. [50.8 mm] in outside diameter, or over 0.135 in. [3.44 mm] in wall thickness, the flash on the inside of the tubes shall be mechanically removed by cutting to a maximum height of 0.010 in. [0.25 mm] at any point on the tube.

12.2 For tubes 2 in. [50.8 mm] and under in outside diameter and 0.135 in. [3.44 mm] and under in wall thickness, the flash on the inside of the tube shall be mechanically removed by cutting to a maximum height of 0.006 in. [0.15 mm] at any point on the tube.

13. Straightness and Finish

13.1 Finished tubes shall be reasonably straight and have smooth ends free of burrs. They shall have a workmanlike finish. It is permitted to remove surface imperfections by grinding, provided that a smooth curved surface is maintained, and the wall thickness is not decreased to less than that permitted by this or the product specification, or the purchase order. The outside diameter at the point of grinding may be reduced by the amount so removed.

TABLE 4 Permitted Variations in Length[A]

Method of Manufacture	Specified Outside Diameter, in. [mm]	Cut Length, in. [mm] Over	Under
Seamless, hot-finished	All sizes	3/16 [5]	0 [0]
Seamless, cold-finished	Under 2 [50.8]	1/8 [3]	0 [0]
	2 [50.8] or over	3/16 [5]	0 [0]
Welded	Under 2 [50.8]	1/8 [3]	0 [0]
	2 [50.8] or over	3/16 [5]	0 [0]

[A] These permitted variations in length apply to tubes before bending. They apply to cut lengths up to and including 24 ft [7.3 m]. For lengths greater than 24 ft [7.3 m], the above over-tolerances shall be increased by 1/8 in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft or ½ in. [13 mm], whichever is the lesser.

14. Repair by Welding

14.1 Repair welding of base metal defects in tubing is permitted only with the approval of the purchaser and with the further understanding that the tube shall be marked "WR" and the composition of the deposited filler metal shall be suitable for the composition being welded. Defects shall be thoroughly chipped or ground out before welding and each repaired length shall be reheat treated or stress relieved as required by the applicable specification. Each length of repaired tube shall be examined by a nondestructive test as required by the product specification.

14.2 Repair welding shall be performed using procedures and welders or welding operators that have been qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

15. Retests

15.1 If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional tubes of double the original number from the same group or lot, each of which shall conform to the requirements specified.

16. Reheat Treatment

16.1 If the individual tubes or the tubes selected to represent any group or lot fail to conform to the test requirements, the individual tubes or the group or lot represented may be reheat treated and resubmitted for test. Not more than two reheat treatments shall be permitted.

17. Test Specimens

17.1 Test specimens shall be taken from the ends of finished tubes prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free of burrs and flaws.

17.2 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

18. Method of Mechanical Testing

18.1 The specimens and mechanical tests required shall be made in accordance with Test Methods and Definitions A 370.

18.2 Specimens shall be tested at room temperature.

18.3 Small or subsize specimens as described in Test Methods and Definitions A 370 may be used only when there is insufficient material to prepare one of the standard specimens. When using small or subsize specimens, the largest one possible shall be used.

19. Flattening Test

19.1 A section of tube not less than 2½ in. [60 mm] in length for seamless tubes and not less than 4 in. [100 mm] in length for welded tubes and for heavily cold-worked tubes

shall be flattened cold between parallel plates in two steps. For welded tubes, the weld shall be placed 90° from the direction of the applied force (at a point of maximum bending). During the first step, which is a test for ductility, no cracks or breaks, except as provided for in 19.4, on the inside, outside, or end surfaces shall occur in seamless tubes, or on the inside or outside surfaces of welded tubes and heavily cold-worked tubes, until the distance between the plates is less than the value of H calculated by the following equation:

$$H = \frac{(1 + e)t}{e + t/D} \quad (2)$$

where:

H = distance between flattening plates, in. [mm],
t = specified wall thickness of the tube, in. [mm],
D = specified outside diameter of the tube, in. [mm], and
e = deformation per unit length (constant for a given grade of steel: 0.07 for medium-carbon steel (maximum specified carbon 0.19 % or greater), 0.08 for ferritic alloy steel, 0.09 for austenitic steel, and 0.09 for low-carbon steel (maximum specified carbon 0.18 % or less)).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the specimen meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

19.2 Surface imperfections in the test specimens before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

19.3 Superficial ruptures resulting from surface imperfections shall not be cause for rejection.

19.4 When low D-to-t ratio tubular products are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than 10.

20. Reverse Flattening Test

20.1 A section 4 in. [100 mm] in length of finished welded tubing in sizes down to and including ½ in. [12.7 mm] in outside diameter shall be split longitudinally 90° on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There shall be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

21. Reverse Bend Test

21.1 A section 4 in. [100 mm] minimum in length shall be split longitudinally 90° on each side of the weld. The sample shall then be opened and bent around a mandrel with a maximum thickness of four times the wall thickness, with the mandrel parallel to the weld and against the original outside surface of the tube. The weld shall be at the point of maximum bend. There shall be no evidence of cracks or of overlaps resulting from the reduction in thickness of the weld area by cold working. When the geometry or size of the tubing make it difficult to test the sample as a single piece, the sample may be sectioned into smaller pieces provided a minimum of 4 in. of weld is subjected to reverse bending.

21.2 The reverse bend test is not applicable when the wall is 10 % or more of the specified outside diameter, or the wall thickness is 0.134 in. [3.4 mm] or greater, or the outside diameter is less than 0.375 in. [9.5 mm]. Under these conditions, the reverse flattening test shall apply.

22. Flaring Test

22.1 A section of tube approximately 4 in. [100 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 to the percentages specified in Table 5 without cracking or showing imperfections rejectable under the provisions of the product specification.

23. Flange Test

23.1 A section of tube shall be capable of having a flange turned over at a right angle to the body of the tube without cracking or showing imperfections rejectable under the provisions of the product specification. The width of the flange for carbon and alloy steels shall be not less than the percentages specified in Table 6. For the austenitic grades, the width of the flange for all sizes listed in Table 6 shall be not less than 15 %.

24. Hardness Test

24.1 For tubes with wall thickness 0.200 in. [5.1 mm] or over, either the Brinell or Rockwell hardness test shall be used. When Brinell hardness testing is used, a 10-mm ball with 3000, 1500, or 500-kg load, or a 5-mm ball with 750-kg load shall be used, at the option of the manufacturer.

24.2 For tubes with wall thickness 0.065 in. [1.7 mm] or over but less than 0.200 in. [5.1 mm], the Rockwell hardness test shall be used.

24.3 For tubes with wall thickness less than 0.065 in. [1.7 mm], the hardness test shall not be required.

24.4 The Brinell hardness test shall, at the option of the manufacturer, be made on the outside of the tube near the end, on the outside of a specimen cut from the tube, or on the wall cross section of a specimen cut from the tube. This test shall be made so that the distance from the center of the impression to the edge of the specimen is at least 2.5 times the diameter of the impression.

24.5 The Rockwell hardness test shall, at the option of the manufacturer, be made on the inside surface, on the wall cross section, or on a flat on the outside surface.

TABLE 5 Flaring Test Requirements

Ratio of Inside Diameter to Specified Outside Diameter[A]	Minimum Expansion of Inside Diameter, %	
	Carbon, Carbon-Molybdenum, and Other Ferritic Alloy Steels	Austenitic Steels
0.9	21	15
0.8	22	17
0.7	25	19
0.6	30	23
0.5	39	28
0.4	51	38
0.3	68	50

[A] In determining the ratio of inside diameter to specified outside diameter, the inside diameter shall be defined as the actual mean inside diameter of the material tested.

TABLE 6 Flange Requirements

Specified Outside Diameter of Tube, in. [mm]	Width of Flange
To 2½ [63.5], incl	15 % of Specified Outside Diameter
Over 2½ to 3¾ [63.5 to 95.2], incl	12½ % of Specified Outside Diameter
Over 3¾ to 8 [95.2 to 203.2], incl	10 % of Specified Outside Diameter

24.6 For tubes furnished with upset, swaged, or otherwise formed ends, the hardness test shall be made as prescribed in 24.1 and 24.2 on the outside of the tube near the end after the forming operation and heat treatment.

24.7 For welded or brazed tubes, the hardness test shall be made away from the joints.

24.8 When the product specification provides for Vickers hardness, such testing shall be in accordance with Test Method E 92.

25. Nondestructive Examination

25.1 Except as provided in 26.1, each tube shall be examined by a nondestructive examination method in accordance with Practice E 213, Practice E 309 (for ferromagnetic materials), Practice E 426 (for non-magnetic materials), or Practice E 570. Upon agreement, Practice E 273 shall be employed in addition to one of the full periphery tests. The range of tube sizes that may be examined by each method shall be subject to the limitations in the scope of that practice. In case of conflict between these methods and practices and this specification, the requirements of this specification shall prevail.

25.2 The following information is for the benefit of the user of this specification.

25.2.1 Calibration standards for the nondestructive electric test are convenient standards for calibration of nondestructive testing equipment only. For several reasons, including shape, orientation, width, and so forth, the correlation between the signal produced in the electric test from an imperfection and from calibration standards is only approximate. A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

25.2.2 The ultrasonic examination referred to in this specification is intended to detect longitudinal discontinuities having a reflective area similar to or larger than the calibration reference notches specified in 25.8. The examination may not detect circumferentially oriented imperfections or short, deep defects.

25.2.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type. Practices E 309 and E 426 contain additional information regarding the capabilities and limitations of eddy-current examination.

25.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. The provisions of this specification only provide for longitudinal calibration for flux leakage. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

25.2.5 The hydrostatic test referred to in Section 25 is a test method provided for in many product specifications. This test has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall defects or defects that extend an appreciable distance into the wall without complete penetration.

25.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular products.

25.3 *Time of Examination*—Nondestructive examination for specification acceptance shall be performed after all deformation processing, heat treating, welding, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

25.4 *Surface Condition*:

25.4.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

25.4.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

25.5 *Extent of Examination*:

25.5.1 The relative motion of the tube and the transducer(s), coil(s), or sensor(s) shall be such that the entire tube surface is scanned, except for end effects as noted in 24.5.2.

25.5.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

25.6 *Operator Qualifications*:

25.6.1 The test unit operator shall be certified in accordance with SNT TC-1-A, or an equivalent documented standard agreeable to both purchaser and manufacturer.

25.7 *Test Conditions*:

25.7.1 For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.0 MHz, and the maximum transducer size shall be 1.5 in. [38 mm].

25.7.2 For eddy current testing, the excitation coil frequency shall be chosen to ensure adequate penetration, yet provide good signal-to-noise ratio.

25.7.2.1 The maximum coil frequency shall be:

Specified Wall Thickness, in. [mm]	Maximum Frequency, kHz
<0.050 in. [1.25]	100
0.050 to 0.150 [1.25 to 3.80]	50
>0.150 [3.80]	10

25.8 *Reference Standards*:

25.8.1 Reference standards of convenient length shall be prepared from a length of tube of the same grade, specified size (outside diameter and wall thickness), surface finish, and heat treatment condition as the tubing to be examined.