Designation: A450/A450M – 21

Standard Specification for General Requirements for Carbon and Low Alloy Steel Tubes[1]

This standard is issued under the fixed designation A450/A450M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This specification[2] covers a group of requirements which, with the exceptions of 6.3 and Sections 7, 8, 19, 20, 21, 22, 23, 24, and 25, are mandatory requirements to the following ASTM tubular product specifications:[3]

Title of Specification	ASTM Designation[4]
Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler Tubes	A178/A178M
Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes	A179/A179M
Seamless Carbon Steel Boiler Tubes for High-Pressure Service	A192/A192M
Seamless Medium-Carbon Steel Boiler and Superheater Tubes	A210/A210M
Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes	A214/A214M
Seamless and Electric-Welded Low-Alloy Steel Tubes	A423/A423M
Specification for Seamless and Welded Carbon Steel Heat-Exchanger Tubes with Integral Fins	A498/A498M
Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes	A556/A556M
Seamless, Cold-Drawn Carbon Steel Tubing for Hydraulic System Service	A822/A822M

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

1.2 One or more of Sections 6.3, 7, 8, 19, 20, 21, 22, 22.1, 24, and 25 apply when the product specification or purchase order has a requirement for the test or analysis described by these sections.

1.3 In case of conflict between a requirement of the product specification and a requirement of this general requirement specification only the requirement of the product specification need be satisfied.

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

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[4]

A178/A178M Specification for Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes

A179/A179M Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes

A192/A192M Specification for Seamless Carbon Steel Boiler Tubes for High-Pressure Service

A210/A210M Specification for Seamless Medium-Carbon Steel Boiler and Superheater Tubes

A214/A214M Specification for Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A423/A423M Specification for Seamless and Electric-Welded Low-Alloy Steel Tubes

A498/A498M Specification for Seamless and Welded Carbon Steel Heat-Exchanger Tubes with Integral Fins

A530/A530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A556/A556M Specification for Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes

[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 ASME Boiler and Pressure Vessel Code applications see related Specification SA-450 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vols 01.01 and 01.04.

[4] 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**

A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
A751 Test Methods and Practices for Chemical Analysis of Steel Products
A822/A822M Specification for Seamless Cold-Drawn Carbon Steel Tubing for Hydraulic System Service
A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A1047/A1047M Test Method for Pneumatic Leak Testing of Tubing
A1058 Test Methods for Mechanical Testing of Steel Products—Metric
D3951 Practice for Commercial Packaging
E92 Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials
E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing
E273 Practice for Ultrasonic Testing of the Weld Zone of Welded Pipe and Tubing
E309 Practice for Eddy Current Examination of Steel Tubular Products Using Magnetic Saturation
E426 Practice for Electromagnetic (Eddy Current) Examination of Seamless and Welded Tubular Products, Titanium, Austenitic Stainless Steel and Similar Alloys
E570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *SAE Aerospace Material Specifications:*
SAE-AMS2806 Identification Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat-Resistant Steels and Alloys[5]

2.3 *Military Standards:*
MIL-STD-792 Identification Marking Requirements for Special Purpose Equipment[6]
NAVSEA T9074-AS-GIB-010/271 Requirements for Nondestructive Testing Methods[7]

2.4 *ASME Boiler and Pressure Vessel Code:*
Section IX[8]

2.5 *Steel Structures Painting Council:*
SSPC-SP 6 Surface Preparation Specification No. 6 Commercial Blast Cleaning[9]

2.6 *Other Document:*
SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification.

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

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

3.1.2 *thin-wall tube*—a tube meeting the specified outside diameter and specified wall thickness set forth as follows:

Specified Outside Diameter	Specified Wall Thickness
2 in. [50.8 mm] or less	2 % or less of specified outside diameter
Greater than 2 in. [50.8 mm]	3 % or less of specified outside diameter
Any	0.020 in. [0.5 mm] or less

3.2 *Other defined terms*—The definitions in Test Methods and Definitions A370, Test Methods, Practices, and Terminology A751, and Terminology A941 are applicable to this specification and to those listed in 1.1.

4. Ordering Information

4.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include, but are not limited to, the following:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Specificiation number with grade or class, or both, as applicable and year date,

4.1.3 Manufacture (hot-finished or cold-finished),

4.1.4 Size (outside diameter and minimum wall thickness),

4.1.5 Length (specific or random),

4.1.6 Choice of testing track from the options listed in Test Methods A1058 when material is ordered to an M suffix (SI units) product standard. If the choice of test track is not specified in the order, then the default ASTM test track shall be used as noted in Test Methods A1058.

4.1.7 Supplementary Requirements, and

4.1.8 Additional requirements.

5. Process

5.1 The steel may be made by any process.

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

5.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, such as electroslag remelting or vacuum-arc remelting.

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

6. Chemical Composition

6.1 Samples for chemical analysis, and method of analysis shall be in accordance with Test Methods, Practices, and Terminology A751.

6.2 *Heat Analysis*—If the heat analysis reported by the steel producer is not sufficiently complete for conformance with the heat analysis requirements of the applicable product specification to be fully assessed, the manufacturer may complete the assessment of conformance with such heat analysis requirements by using a product analysis for the specified elements that were not reported by the steel producer, provided that product analysis tolerances are not applied and the heat analysis is not altered.

[5] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

[6] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.

[7] Available from Naval Inventory Control Point, Code 1 Support Branch, 700 Robbins Ave., Philadelphia, PA 19111-5094.

[8] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[9] Available from Society for Protective Coatings (SSPC), 40 24th St., 6th Floor, Pittsburgh, PA 15222-4656, http://www.sspc.org.

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

7. Tensile Properties

7.1 The material shall conform to the requirements as to tensile properties prescribed in the individual specification.

7.2 The yield strength 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 shall be determined.

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 Weights

8.1 The calculated weight per unit length, based upon a specified minimum wall thickness, shall be determined by the following equation:

$$W = C(D - t)t \quad (1)$$

where:

C = 10.69 [0.0246615],
W = weight, lb/ft [kg/m],
D = specified outside diameter, in. [mm], and
t = specified minimum wall thickness, in. [mm]

8.2 The permissible variations from the calculated weight per foot [kilogram per metre] shall be as prescribed in Table 1.

9. Permissible 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. [50.8 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 permissible variations in wall thickness for hot-finished tubes shall apply.

TABLE 1 Permissible Variations in Weight Per Unit Length[A]

Method of Manufacture	Permissible Variation in Weight per Unit Length, %	
	Over	Under
Seamless, hot-finished	16	0
Seamless, cold-finished:		
1½ in. [38.1 mm] and under OD	12	0
Over 1½ in. [38.1 mm] OD	13	0
Welded	10	0

[A] These permissible variations in weight 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 Permissible 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 0.180 [3.8 to 4.6], incl		Over 0.180, [4.6]	
	Over	Under	Over	Under	Over	Under	Over	Under
Seamless, Hot-Finished Tubes								
4 [101.6] and under	40	0	35	0	33	0	28	0
Over 4 [101.6]	...	...	35	0	33	0	28	0

	Over	Under
Seamless, Cold-Finished Tubes		
1½ [38.1] and under	20	0
Over 1½ [38.1]	22	0
Welded Tubes		
All sizes	18	0

[A] These permissible 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. Permissible Variations in Outside Diameter

10.1 Except as provided in 10.2, 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. 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:

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

TABLE 3 Permissible Variations in Outside Diameter[A]

Outside Diameter, in. [mm]	Permissible Variations, in. [mm]	
	Over	Under
Hot-Finished Seamless Tubes		
4 [101.6] and under	1/64 [0.4]	1/32 [0.8]
Over 4 to 7½ [101.6 to 190.5], incl	1/64 [0.4]	3/64 [1.2]
Over 7½ to 9 [190.5 to 228.6], incl	1/64 [0.4]	1/16 [1.6]
Welded Tubes and Cold-Finished Seamless Tubes		
Under 1 [25.4]	0.004 [0.1]	0.004 [0.1]
1 to 1½ [25.4 to 38.1], incl	0.006 [0.15]	0.006 [0.15]
Over 1½ to 2 [38.1 to 50.8], excl	0.008 [0.2]	0.008 [0.2]
2 to 2½ [50.8 to 63.5], excl	0.010 [0.25]	0.010 [0.25]
2½ to 3 [63.5 to 76.2], excl	0.012 [0.3]	0.012 [0.3]
3 to 4 [76.2 to 101.6], incl	0.015 [0.38]	0.015 [0.38]
Over 4 to 7½ [101.6 to 190.5], incl	0.015 [0.38]	0.025 [0.64]
Over 7½ to 9 [190.5 to 228.6], incl	0.015 [0.38]	0.045 [1.14]

[A] Except as provided in 10.2, these permissible variations include out-of-roundness. These permissible 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.

11. Permissible Variations in Length

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

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

12.1 For tubes manufactured to this specification, the weld flash on the outside of the tube shall be mechanically removed by cutting prior to any subsequent cold work or sizing.

12.2 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.

12.3 For tubes 2 in. [50.8 mm] and under in outside diameter and 0.135 in. [3.4 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. Surface imperfections (see Note 1) may be removed 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. The outside diameter at the point of grinding may be reduced by the amount so removed.

NOTE 1—An imperfection is any discontinuity or irregularity found in the tube.

14. Repair by Welding

14.1 Repair welding of base metal defects in tubing is permissible 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 tested hydrostatically as required by the product specification.

TABLE 4 Permissible Variations in Length[A]

Method of Manufacture	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] and over	3⁄16 [5]	0 [0]
Welded	Under 2 [50.8]	1⁄8 [3]	0 [0]
	2 [50.8] and over	3⁄16 [5]	0 [0]

[A] These permissible 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.

14.2 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. Retreatment

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 retreated 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 Annex A2 of Test Methods and Definitions A370 if inch-pound units are specified or to the requirements described in the applicable track of Test Methods A1058 if SI units are specified.

18.2 Specimens shall be tested at room temperature.

18.3 Small or subsize specimens as described in Test Methods and Definitions A370 or Test Methods A1058 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 2 ½ in. [63 mm] in length for seamless and not less than 4 in. [100 mm] in length for welded 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, 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 low alloy 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 tube 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 5 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. Flaring Test

21.1 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.

TABLE 5 Flaring Test Requirements

Ratio of Inside Diameter to Outside Diameter[A]	Minimum Expansion of Inside Diameter, %	
	Carbon Steels	Low Alloy 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.

22. Flange Test

22.1 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.

23. Hardness Test

23.1 For tubes 0.200 in. [5.1 mm] and over in wall thickness, 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 may be used, at the option of the manufacturer.

23.2 For tubes less than 0.200 in. [5.1 mm] to and including 0.065 in. [1.7 mm] in wall thickness, the Rockwell hardness test shall be used.

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

23.4 The Brinell hardness test may 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 at the option of the manufacturer. 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.

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

23.6 For tubes furnished with upset, swaged, or otherwise formed ends, the hardness test shall be made as prescribed in 23.1 and 23.2 on the outside of the tube near the end after the forming operation and heat treatment.

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

23.8 When the product specification provides for Vickers hardness, such testing shall be in accordance with Test Method E92.

24. Hydrostatic Test

24.1 Except as provided in 24.2 and 24.3, each tube shall be tested by the manufacturer to a minimum hydrostatic test pressure determined by the following equation:

$$Inch - Pound\ Units: P = 32000\,t/D \quad (3)$$

$$SI\ Units: P = 220.6t/D$$

TABLE 6 Flange Requirements

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

where:

P = hydrostatic test pressure, psi or MPa,

t = specified wall thickness, in. or mm, and

D = specified outside diameter, in. or mm.

24.1.1 The hydrostatic test pressure determined by Eq 3 shall be rounded to the nearest 50 psi [0.5 MPa] for pressure below 1000 psi [7 MPa], and to the nearest 100 psi [1 MPa] for pressures 1000 psi [7 MPa] and above. The hydrostatic test may be performed prior to cutting to final length, or prior to upsetting, swaging, expanding, bending or other forming operations, or both.

24.2 Regardless of the determination made by Eq 3, the minimum hydrostatic test pressure required to satisfy these requirements need not exceed the values given in Table 7. This does not prohibit testing at higher pressures at manufacturer's option or as provided in 24.3.

24.3 With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements of 24.2 or 24.1, or both, may be stated on the order. The tube wall stress shall be determined by the following equation:

$$S = PD/2t \quad (4)$$

where:

S = tube wall stress, psi or MPa, and all other symbols as defined in 24.1.1.

24.4 The test pressure shall be held for a minimum of 5 s.

24.5 If any tube shows leaks during the hydrostatic test, it shall be rejected.

24.6 The hydrostatic test may not be capable of testing the end portion of the pipe. The lengths of pipe that cannot be tested shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

25. Air Pressure Test

25.1 *Air Underwater Test*—When this test is employed, each tube, with internal surface clean and dry, shall be internally pressurized to 150 psi [1000 kPa] minimum with clean and dry compressed air while being submerged in clear water. The tube shall be well-lighted, preferably by underwater illumination. Any evidence of air leakage of the pneumatic couplings shall be corrected prior to testing. Inspection shall be made of the entire external surface of the tube after holding the pressure for not less than 5 s after the surface of the water has become calm. If any tube shows leakage during the air underwater test, it shall be rejected. Any leaking areas may be cut out and the tube retested.

TABLE 7 Hydrostatic Test Pressures

Outside Diameter of Tube, in. [mm]	Hydrostatic Test Pressure, psi [MPa]
Under 1 [25.4]	1000 [7]
1 to 1½ [25.4 to 38.1], excl	1500 [10]
1½ to 2 [38.1 to 50.8], excl	2000 [14]
2 to 3 [50.8 to 76.2], excl	2500 [17]
3 to 5 [76.2 to 127], excl	3500 [24]
5 [127] and over	4500 [31]

25.2 *Pneumatic Leak Test*—When this test is employed, each tube shall be subjected to a pneumatic leak test in accordance with Specification A1047/A1047M.

Acceptance criteria shall be as follows:

Tube O.D. in [mm]	Calibration Hole, max. in [mm]
≤1.5 [≤40]	0.003 [0.076]
>1.5≤2.0 [>40≤50]	0.004 [0.162]
>2.0≤2.5 [>50≤65]	0.005 [0.127]
>2.5≤3.0 [>65≤75]	0.006 [0.152]
>3.0 [>75]	by agreement

26. Nondestructive Examination

26.1 When nondestructive examination is specified by the purchaser or the product specification, each tube shall be examined by a nondestructive examination method in accordance with Practice E213, Practice E309 (for ferromagnetic materials), Practice E426 (for non-magnetic materials), or Practice E570. Upon agreement, Practice E273 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.

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

26.2.1 Calibration standards for the nondestructive electric test are convenient standards for calibration of nondestructive testing equipment only. For several reasons, including shape, orientation, width, etc., 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.

26.2.2 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 26.4. The examination may not detect circumferentially oriented imperfections or short, deep defects.

26.2.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type. Practices E309 and E426 contain additional information regarding the capabilities and limitations of eddy-current examination.

26.2.4 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.

26.2.5 The hydrostatic test referred to in Section 23 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.

26.2.6 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.

26.3 *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.

26.4 *Surface Condition:*

26.4.1 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.

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

26.5 *Extent of Examination:*

26.5.1 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 26.5.2.

26.5.2 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.

26.6 *Operator Qualifications:*

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

26.7 *Test Conditions:*

26.7.1 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].

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

26.7.2.1 The maximum coil frequency shall be:

Specified Wall Thickness	Maximum Frequency
<0.050 in.	100 KHz
0.050 to 0.150	50
>0.150	10

26.8 *Reference Standards:*

26.8.1 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.

26.8.2 *For eddy current testing,* the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

26.8.2.1 *Drilled Hole*—The reference standard shall contain three or more holes, equally spaced circumferentially around the tube and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the tube wall, with care being taken to avoid distortion of the tube while drilling. The holes shall not be larger than 0.031 in. [0.8 mm] in diameter. As an alternative, the producer may choose to drill one hole and run the calibration standard through the test coil three times, rotating the tube approximately 120° each time. More passes with smaller angular increments may be used, provided testing of the full 360° of the coil is obtained. For welded tubing, if the weld is visible, one of the multiple holes or the single hole shall be drilled in the weld.

26.8.2.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼ in. [6.4 mm] diameter, a notch shall be milled or filed tangential to the surface and transverse to the longitudinal axis of the tube. Said notch shall have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater.

26.8.2.3 *Longitudinal Notch*—A notch 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

26.8.3 *For ultrasonic testing,* the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E213, at the option of the manufacturer. The depth of the notches shall not exceed 12½ % of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater. The width of the notch shall not exceed two times the depth. For welded tubing, the notches shall be placed in the weld, if the weld is visible.

26.8.4 *For flux leakage testing,* the longitudinal reference notches shall be straight-sided notches machined in a radial plane parallel to the tube axis on the inside and outside surfaces of the tube. Notch depth shall not exceed 12½ % of the specified wall thickness or 0.004 in. [0.1 mm], whichever is greater. Notch length shall not exceed 1 in. [25.4 mm], and the width shall not exceed the depth. Outside and inside notches shall have sufficient separation to allow distinct identification of the signal from each notch.

26.8.5 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

26.9 *Standardization Procedure:*

26.9.1 The test apparatus shall be standardized at the beginning and end of each series of tubes of the same specified size (diameter and wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h during the examination of such tubing. More frequent standardizations may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

26.9.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss or shutdown.