Designation: A 556/A 556M – 96 (Reapproved 2005)

Standard Specification for Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes[1]

This standard is issued under the fixed designation A 556/A 556M; 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[2] covers minimum-wall-thickness, seamless cold-drawn carbon steel tubes including bending into the form of U-tubes, if specified, for use in tubular feedwater heaters.

1.2 The tubing sizes covered shall be ⅝ to 1¼-in. [15.9 to 31.8-mm] outside diameter, inclusive, with minimum wall thicknesses equal to or greater than 0.045 in. [1.1 mm].

1.3 Optional supplementary requirements are provided, and when desired, shall be stated in the order.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as the 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 of this specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[4]

3. Ordering Information

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

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

3.1.2 Name of material (seamless steel tubing),

3.1.3 Dimensions (outside diameter and minimum wall thickness),

3.1.4 Length (specific or random),

3.1.5 Manufacture (cold drawn),

3.1.6 Grade (chemical composition),

3.1.7 Optional requirements,

3.1.8 *Bending Requirements*— If order specifies tubes to be bent, the design of the U-tubes shall accompany the order. Purchaser must specify if stress-relief anneal of the U-bends is required,

3.1.9 Test report required (see Certification Section of Specification A 450/A 450M),

3.1.10 Specification number, and

3.1.11 Special requirements and any supplementary requirements selected.

4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of the Specification A 450/A 450M, unless otherwise provided herein.

5. Manufacture

5.1 *Manufacture*—Tubes shall be made by the seamless process and shall be cold drawn.

5.2 *Heat Treatment*:

5.2.1 Cold-drawn tubes shall be heat treated after the final cold-draw pass at a temperature of 1200°F [640°C] or higher to ensure ductility satisfactory for rolling into tube sheets and to meet mechanical properties as specified.

5.2.2 If stress-relief anneal of the U-bends is specified, the anneal shall consist of heating the bent portion within a range of 1100 to 1200°F [585 to 640°C].

6. Chemical Composition

6.1 The steel shall conform to one of the requirements as to chemical composition as prescribed in Table 1.

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[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-556 in Section II of that Code.

[3] 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.

[4] Withdrawn.

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TABLE 1 Chemical Requirements

Element	Composition, %		
	Grade A2	Grade B2	Grade C2
Carbon, max	0.18	0.27	0.30
Manganese	0.27–0.63	0.29–0.93	0.29–1.06
Phosphorus, max	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035
Silicon, min	...	0.10	0.10

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

7. Product Analysis

7.1 When requested in the purchase order, a product analysis shall be made by the manufacturer or supplier from one tube or billet per heat.

7.2 If the original test for product analysis fails, retests of two additional tubes or billets shall be made. Both retests for the elements in question shall meet the requirements of this specification; otherwise, all remaining material in the heat or lot (Note 1) shall be rejected or, at the option of the producer, each tube may be individually tested for acceptance. Tubes that do not meet the requirements of this specification shall be rejected.

NOTE 1—For tension and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat and furnace speed.

7.3 For referee purposes, Test Methods E 30 shall be used.

8. Mechanical Properties

8.1 *Tensile Properties*—The material shall conform to the requirements as to tensile properties prescribed in Table 2, when pulled in full section.

8.2 *Hardness Requirements*—The tubes shall not exceed the Rockwell Hardness shown in Table 3.

9. Permissible Variations in Dimensions (Fig. 1)

9.1 Permissible variations from the specified outside diameter shall not exceed ±0.004 in. [0.10 mm] for tubing under 1.0-in. [25.4-mm] outside diameter nor ±0.006 in. [0.15 mm] for tubing 1.0 in. [25.4 mm] to 1.25 in. [31.7 mm] inclusive. These tolerances do not apply to the bent portion of the U-tubes. At the bent portion of a U-tube for $R = 2 \times D$ or greater neither the major nor minor diameter of tube shall deviate from nominal by more than 10 %. If 1½ *D* is specified, tolerances could be greater.

TABLE 2 Tensile Requirements

	Grade A2	Grade B2	Grade C2
Tensile strength, min, ksi [MPa]	47 [320]	60 [410]	70 [480]
Yield strength, min, ksi [MPa]	26 [180]	37 [260]	40 [280]
Elongation in 2 in. or 50 mm, min, % (longitudinal)	35	30	30

TABLE 3 Hardness Requirements

Grade A2	HR B 72
Grade B2	HR B 79
Grade C2	HR B 89

9.2 Permissible variations from the specified minimum wall thickness shall not exceed +20 % or −0. The wall thickness of the tube in U-bent section shall be not less than value determined by:

$$t_f = T\,(2R) / (2R+D) \quad (1)$$

where:

t_f = wall thickness after bending, in. [mm],
T = specified minimum tube wall thickness, in. [mm],
R = centerline bend radius, in. [mm], and
D = nominal outside tube diameter, in. [mm].

9.3 In the case of U-tubes, the length of the tube legs as measured from the point of tangency of the bend and the tube leg to the end of the tube leg shall not be less than specified, but may exceed the specified values by the amount given in Table 4. The difference in lengths of the tube legs shall not be greater than ⅛ in. [3 mm] unless otherwise specified.

9.4 The end of any tube may depart from square by not more than the amount given in Table 5.

9.5 The leg spacing measured between the points of tangency of the bend to the legs shall not vary from the value (2*R* − specified tube OD) by more than 1/16 in. [1.5 mm] where *R* is the centerline bend radius.

9.6 The bent portion of the U-tube shall be substantially uniform in curvature and not exceed ±1/16 in. [±1.5 mm] of the normal centerline radius.

10. Workmanship, Finish, and Appearance

10.1 Finished tubes shall be free from scale but may have a superficial oxide film on the surfaces. A light oxide scale on the outside and inside surfaces of U-bend shall be allowed for tubes which have been heat treated.

10.2 Finished tubes shall be reasonably straight and have smooth ends free from burrs. Tubes shall have a workmanlike finish and shall be free of surface imperfections that cannot be removed within the allowable wall tolerances. Removal of surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be required provided they are within the allowable wall tolerances.

10.3 Finished tubes shall be coated both on the outside and the inside diameter to prevent corrosion in transit. The type of coating applied should be mutually agreed upon and specified in the order.

11. Mechanical Tests Required

11.1 *Tension Test*—One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (Note 1).

11.2 *Flattening Test*—One flattening test shall be made on specimens taken from each end of one finished tube, not the

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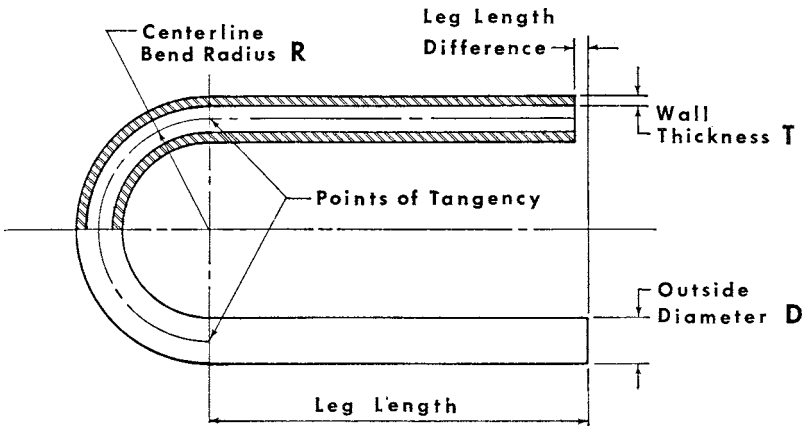

FIG. 1 Bent Portion of U-Tube

TABLE 4 Tube Leg Length Tolerance

Leg Length, ft [m]	Plus Tolerance in. [mm]
Up to 20 [6], incl	1/8 [3.2]
Over 20 to 30 [6 to 9], incl	5/32 [4.0]
Over 30 to 40 [9 to 12.2], incl	3/16 [4.8]

TABLE 5 Squareness of Ends Tolerance

Tube OD, in. [mm]	Tolerance, in. [mm]
5/8 [15.9]	0.010 [0.25]
Over 5/8 to 1 1/4 [15.9 to 31.7], incl	0.016 [0.4]

one used for the flaring test, from each lot of not more than 125 tubes or fraction thereof.

11.3 *Flaring Test*—One flaring test shall be made on specimens taken from each end of one finished tube, not the one used for flattening test, from each lot of not more than 125 tubes or fraction thereof.

11.4 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 1).

11.5 *Hydrostatic Test*—Each U-tube shall be subjected to a hydrostatic test, using a noncorrosive fluid, or when agreed upon between the purchaser and manufacturer, they may be tested at 1½ times the specified design working pressure.

12. Nondestructive Test (Electric Test)

12.1 Each tube shall be tested after the finish heat treatment following the final cold-drawn pass by passing through a nondestructive tester capable of detecting defects on the entire cross section of the tube, in accordance with Specification A 450/A 450M.

13. Packaging and Package Marking

13.1 The tubing shall be packaged or bundled in such a manner as to prevent damage in ordinary handling and transportation and identified by a tag with the name of the manufacturer, purchase order number, specification number and grade, and size.

13.2 In the case of U-tubes, each box shall be palletized and legibly marked showing the manufacturer's name, purchase order number, specification number and grade, size, and identification of items contained.

13.3 *Bar Coding*—In addition to the requirements in 13.1 and 13.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

14. Keywords

14.1 carbon; feedwater heater tubes; seamless steel tube; steel tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement or requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order, in which even the necessary tests shall be made by the manufacturer prior to the bending or shipment of the tubing.

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S1. Nondestructive Ultrasonic Test—Round Tubing (Commercial Grade)

S1.1 The manufactuer shall test the tubing by an ultrasonic nondestructive test for detection of harmful faults and soundness.

S1.1.1 Ultrasonic testing shall be performed using pulse-echo shear wave techniques to locate longitudinal or circumferential defects, or both.

S1.1.2 Tubes being tested shall be reasonably straight for proper rotation. The outside and inside diameter surfaces of the tubes shall be free of dirt, grit, grease, oil, loose scale, or other materials which tend to attenuate, scatter, or reflect ultrasonic signals.

S1.1.3 Tubing shall be inspected by feeding spirally past a suitable transducer with rotation of material to be toward the transducer.

S1.1.4 Suitable ultrasonic instrumentation shall be used to clearly distinguish the artificial defects (hereafter called reference notches) described later. Automatic electronic monitoring of the reflected ultrasonic signals shall be provided in such manner that any naturally occurring defects which present an ultrasonic reflection equal to or greater than the reference standard(s) shall trigger audible and visible alarms.

S1.1.5 Instrument calibration as described herein shall be accomplished with the reference standard being rotated and fed past the transducer at the same approximate rate at which the tubing under test will be tested.

S1.1.6 The following factors will be adjusted so as to achieve optimum instrument distinction between the reference notch(es) and plain portion of tubing when calibrating equipment to the reference standard:

S1.1.6.1 Search unit position shall be such that shear waves are propagated within the tube being tested. If both outside and inside diameter reference notches are used, the optimum angle shall be used which will indicate both notches as close to equal size as possible.

S1.1.6.2 The test frequency to be used shall be chosen to yield the best distinction between reference notches and plain areas of tubing. In general, 2.25 or 5.0 MHz will be used.

S1.1.6.3 Instrument sensitivity shall be adjusted to allow reference notch or notches to present a pip or pips on the scope screen at 50 % to 70 % of instrument saturation level. The Automatic Defect Monitoring System shall be adjusted to monitor by means of electronic gates, the portion of the screen where the reference notch is presented. The sensitivity of the alarm system shall be adjusted to indicate audibly and visibly when the reference notch is fed past the search unit.

S1.1.6.4 The recording equipment, if agreed upon, shall be adjusted to clearly indicate the reference notch or notches and also whether or not any reflected signals actuate the alarm system.

S1.1.7 A reference standard of an appropriate length (sufficient to allow in-line feeding) shall be prepared from a randomly selected tube of the same size, grade, and physical condition as the material to be tested.

S1.1.8 The reference standard shall contain machined notches as follows: Notch to be 10 % of wall thickness in depth but not less than 0.004 in. [0.10 mm]. Tolerance on depth +0.0000 in. or −0.001 in. [0.03 mm].

S1.1.8.1 *Notch Locations and Orientation*—Notches shall be located on outside or inside diameter, or both, and shall be oriented to lie in a longitudinal direction for radial inspection or circumferentially, or both, for transverse inspection. The notch or notches shall be located in the reference tube in such a manner that no physical or acoustical interference exists between notches or end of reference tube. These various locations and orientations will be classified as follows:

Type A—Longitudinal outside diameter for radial inspection,

Type B—Longitudinal inside diameter for radial inspection,

Type C—Circumferential outside diameter for transverse inspection, and

Type D—Circumferential inside diameter for transverse inspection.

S1.1.8.2 *Standard Nomenclature*—The size, location, and orientation of the reference notches, which become a part of a particular order covered under this specification, shall be specified.

S1.1.9 The basic procedure will be to rotary feed all the tubes in the order past the search unit (transducer) with the feed helix less than the scanning width of the search unit. As the tubes are fed past the transducer, the alarm system shall be observed for indications of defects equal to or greater than the reference standard. Tubes which show such indications shall be rejected.

S1.1.10 Standard procedure will be to test the material in one direction of helical feed only. Testing in both directions may be done if so specified by customer.

S1.1.11 Any tubes that do not show indications above the level determined by the reference standard shall be held in a lot until the reference standard is run and instrument calibration is proved by triggering alarm system on the reference notch or notches. After calibration is proved to have been correct, this lot of tubes shall be considered tested and accepted as to maximum defect size corresponding to the reference standard used.

S1.1.12 Rejected tubing may be salvaged by polishing or other suitable means when practical and retested after the elimination of the cause of rejection. Such material that meets the dimensional requirements and does not cause triggering of ultrasonic alarm system upon retesting shall be considered as having met the requirements of this supplement.

S2. Nondestructive Ultrasonic Test—Round Tubing (Select Commercial Grade)

S2.1 The manufacturer shall test the tubing using the procedure outlined in Supplementary Requirement S1, except for the notch depth, which shall be 5 % of wall thickness in depth but not less than 0.004 in. [0.10 mm]. Tolerance on depth shall be +0.000 in. or −0.0005 in. [0.01 mm].

S3. Nondestructive Eddy-Current Test

S3.1 Each tube shall be tested after the finish heat treatment following the final cold-draw pass by passing through an electric nondestructive tester capable of detecting defects on the entire cross section of the tube. Suitable instrumentation

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shall be used to clearly distinguish artificial defects or reference notches. Tubes to be tested shall be reasonably straight and the outside and inside diameter surfaces shall be free of loose scale, metallic particles, or other material which would tend to restrict signals or create electrical noise. The tubing shall be inspected by feeding longitudinally through an inspection coil or coils of a diameter suitable for the diameter of tubing to be inspected. The instrument calibration shall be accomplished with a reference standard prepared from an appropriate length of selected tubing of the same size, grade, and physical condition as the material to be inspected. The standard shall be fed through the coil at the same speed at which the inspection of the tubing is performed. The following factors shall be selected or adjusted, or both, in accordance with the instrument manufacturer's instructions for the particular instrument involved as required to achieve optimum instrument distinction between the reference defects and plain portion of the tube. These as well as other factors involved shall not be used in such a manner that they detract from the instrument's overall ability to detect injurious defects:

S3.1.1 Test frequency,
S3.1.2 Direct-current saturation level,
S3.1.3 Filter networks,
S3.1.4 Phase analysis circuits,
S3.1.5 Coil diameter, and
S3.1.6 Instrument gain.

S3.2 The reference standard shall contain longitudinal and circumferential notches in the outside diameter and shall be used to establish the rejection level for the tubing to be tested. Inside diameter notches, both longitudinal and circumferential, shall also be a part of the reference standard. These notches may be larger than outside diameter notches and are intended for use only to assure instrument phase settings capable of yielding optimum inside diameter surface sensitivity. The outside diameter reference notches shall have a depth equal to 10 % of the wall thickness. The tolerance of the notch shall be ±8 % or 0.0005 in. [0.01 mm], whichever is greater. Width of notch shall not exceed twice the depth. The length of the reference notches shall not exceed 0.375 in. [9.5 mm]. All tubing including that which may be reconditioned, provided the dimensional or other properties of the tubing are not adversely affected and provided the tubing does not show indications above the level determined by the outside diameter references, shall meet this specification provided the instrument calibration is verified by indicating the standard outside diameter reference notches of a given lot. Tubes generating a signal above the calibration standard sensitivity level shall be rejected. Tubes may be reconditioned if not adversely affecting the dimensional or other properties of the tube and so tested as to assure a satisfactory tube within the limits of this specification. All tubing shall be demagnetized after inspection has been completed.

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