Designation: A1098/A1098M – 18 (Reapproved 2022)

Standard Specification for Welded Austenitic, Ferritic, Martensitic and Duplex Stainless Steel Boiler, Superheater, Condenser, and Heat Exchanger Tubes with Textured Surface(s)[1]

This standard is issued under the fixed designation A1098/A1098M; 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 average or minimum-wall thickness welded tubes made from various grades of austenitic, ferritic, martensitic and duplex stainless steel materials in which the (*1*) external tube surface, (*2*) internal tube surface, or (*3*) both internal and external tube surfaces have a textured configuration for improved heat transfer or fluid flow or both. Texture surface(s) are produced by cold forming a specified configuration on the surface(s) of base strip material, prior to welding. The produced welded textured tubes may be used in boilers, superheaters, condensers, evaporators, heat exchangers, and other similar heat transfer apparatus in diameters up to and including 1.5 in. [38 mm] for various wall thicknesses up to and including 0.079 in. [2 mm].

1.2 The tubing sizes and thicknesses usually furnished to this specification are 0.375 in. [10 mm] inside diameter (ID) to 1.5 in. [38 mm] outside diameter and 0.020 to 0.079 in. [0.5 to 2 mm], inclusive, in wall thickness. Tubing having other dimensions may be furnished provided such tubes comply with all other requirements of this specification.

1.3 Optional supplementary requirements are provided and, when one or more of these are desired, each shall be so stated in the order.

1.4 Several grades of austenitic, ferritic, martensitic and duplex stainless steels are included in this specification. Not all alloys are suitable for all conditions. Selection will depend upon design and service requirements.

1.5 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 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 of this specification is specified in the order.

1.6 The following safety hazards statement pertains only to the test method and the Supplementary Requirements of this specification. A specific warning statement is given in the Supplementary Requirements. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *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:*[2]

A249/A249M Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A268/A268M Specification for Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

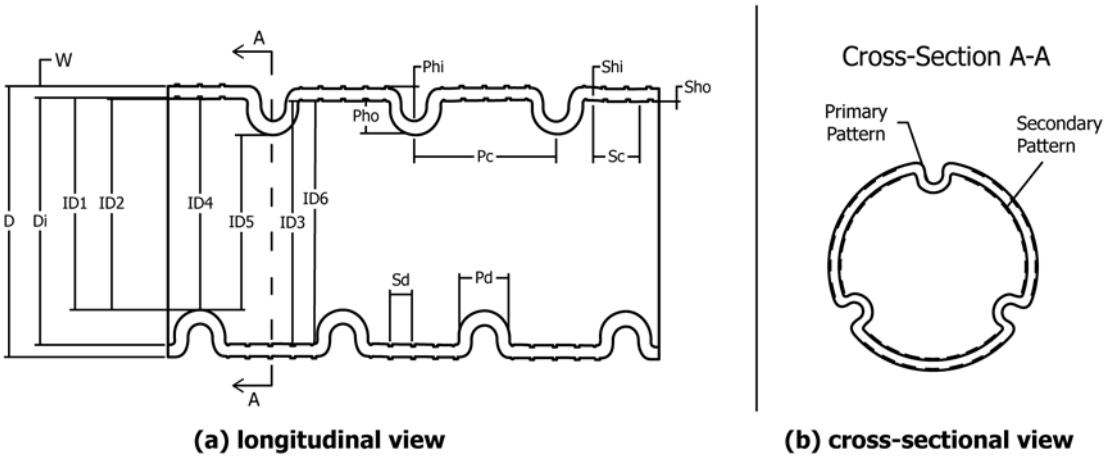
A763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

A789/A789M Specification for Seamless and Welded

[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.

Current edition approved Sept. 1, 2022. Published October 2022. Originally approved in 2016. Last previous edition approved in 2018 as A1098/A1098M – 18. DOI: 10.1520/A1098_A1098M-18R22.

[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) longitudinal view **(b) cross-sectional view**

FIG. 1 Views of a Representative Textured Tube Showing Variables that Describe the Possible Primary and Secondary Texturizations that May be Applied to the Inside Surface of a Tube, Outside Surface of the Tube, or Both the Inside and Outside Surfaces of the Tube

Ferritic/Austenitic Stainless Steel Tubing for General Service

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A1016/A1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E384 Test Method for Microindentation Hardness of Materials

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *ASME Standard:*[3]

Boiler and Pressure Vessel Code Section VIII Para UW-51

2.3 *SAE Standards:*[4]

SAE J1086 Practice for Numbering Metals and Alloys (UNS)

3. Terminology

3.1 For definitions of general terms used in this specification, refer to Terminology A941.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *plain cylindrical ring gauges, n*—a cylindrical metal ring whose inside diameter is furnished to gauge tolerance.

3.2.2 *plain ending, n*—portion of the tube that has no surface texture.

3.2.3 *primary character, n*—largest texture impressed on material.

3.2.4 *primary pattern, n*—combination of primary characters.

3.2.5 *secondary character, n*—finecut texture impressed on material.

3.2.6 *secondary pattern, n*—combination of secondary characters.

3.2.7 *textured surface, n*—impressing a series of characters or textures into the material with the intent of improving heat transfer and fluid flow characteristics in the final welded tube.

3.3 *Symbols:*

3.3.1 *D*—outside tube diameter-nominal

3.3.2 D_i—inside tube diameter

3.3.3 *ID1*—top of primary character to bottom of secondary character. See Fig. 1 cross section A-A for view of primary character and secondary character pattern.

3.3.4 *ID2*—top of primary character to top of secondary character

3.3.5 *ID3*—top of secondary character to top of secondary character

3.3.6 *ID4*—top of primary character to bottom of primary character at intersection of the base (each on opposite sides of the tube)

3.3.7 *ID5*—top of primary character to top of primary character (each on opposite sides of the tube)

3.3.8 *ID6*—top of secondary character to bottom of secondary character

3.3.9 P_a—angle of the primary character unit (if any)

3.3.10 P_a—angle of the secondary character unit (if any)

3.3.11 P_c—primary character center spacing

3.3.12 P_d—primary character diameter

3.3.13 P_{hi}—primary character height (inside)

3.3.14 P_{ho}—primary character height (outside)

3.3.15 S_c—secondary character center spacing

3.3.16 S_d—secondary character diameter

3.3.17 S_{hi}—secondary character height (inside)

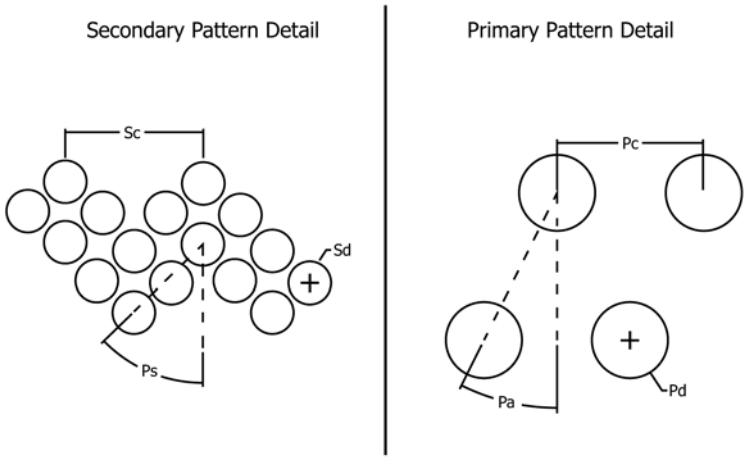
3.3.18 S_{ho}—secondary character height (outside)

3.3.19 *W*—wall thickness (no pattern)

3.3.20 W_1—wall thickness peak inside to valley outside (secondary character)

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

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



(a) Sample secondary (background) surface **(a) Sample primary surface**

NOTE — One, both, or more patterns may be used and combined. Each pattern made up of a variety of possible shapes.

FIG. 2 Details Regarding the Sample Representative Geometry of the Patterns Used to Texture the Flat Strip Material before It is Used to Create a Welded Tube

3.3.21 W_2—wall thickness valley inside to peak outside (secondary character)

3.3.22 W_3—wall thickness base of primary character

3.3.23 W_4—wall thickness in wall of the primary character

4. Ordering Information

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

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

4.1.2 Name of material welded tubes (WLD);

4.1.3 Grade (refer to Table 1);

4.1.4 Size (outside diameter and wall thickness);

4.1.5 Length (specific or random);

4.1.6 Hydrostatic testing or non-destructive electric testing (see Section 16);

4.1.7 Test report required (see Certification Section of Specification A1016/A1016M);

4.1.8 Specification designation;

4.1.9 Special requirements and any supplementary requirements selected.

4.1.9.1 Additional requirements may include the various inside or outside diameters (Fig. 1), texture wall thickness values (see Fig. 3), and length of untextured sections if required; effective diameter and wall thickness of the modified section; number of secondary textured character units per unit length; number of primary textured character units per unit length; and the total tube length.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A1016/A1016M unless otherwise provided herein.

6. Manufacture

6.1 The strip used to form welded tubes shall be textured by cold working on one or both surfaces before being formed into a tube.

6.2 The tubes may have plain ends or have untextured sections within the tube length as specified in the purchase order.

6.3 The tubes shall be made from flat rolled steel using an automatic welding process with no addition of filler metal.

6.4 Subsequent to welding and before final heat treatment, the tubes may be worked only in the welded portion. Cold working and the method of cold working shall be at the option of the manufacturer unless specified otherwise in the purchase order.

7. Chemical Composition

7.1 The heat analysis shall conform to the chemical composition requirements given in Table 1.

8. Heat Treatment

8.1 Austenitic stainless steel tubes shall be provided in the solution annealed condition as specified in Table 2.

8.2 Ferritic stainless steels shall be given a final heat treatment of 1200°F [650°C] or higher and cooled as appropriate for the grade to meet the requirement of this specification.

8.3 For Type 44, annealing is done at 1500 to 1550°F [815 to 842°C] for 1 hr per inch [25 mm] of thickness and furnace cool to room temperature.

8.4 Martensitic stainless steel tubing shall be given a final heat treatment by reheating to a temperature of 1200°F [650°C] or higher and cooled (as appropriate for the grade) to meet the requirements of this specification.

TABLE 1 Chemical Composition Requirements, %[A]

UNS Designation[B]	Type[C]	Carbon[D]	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements[E,F]
Austenitic (Chromium-Nickel) (Chromium-Nickel-Molybdenum) Stainless Steel												
N08904	904L	0.020	2.00	0.045	0.035	1.00	19.0–23.0	23.0–28.0	4.00–5.00	0.10	1.00–2.00	. . .
S30103	301L[G]	0.03	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	. . .	0.20	. . .	. . .
S30153	301LN[G]	0.03	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	. . .	0.07–0.20	. . .	. . .
S30200	302	0.15	2.00	0.045	0.030	0.75	17.0–19.0	8.0–10.0	. . .	0.10	. . .	. . .
S30400	304	0.07	2.00	0.045	0.030	0.75	17.5–19.5	8.0–10.5	. . .	0.10	. . .	. . .
S30403	304L	0.030	2.00	0.045	0.030	0.75	17.5–19.5	8.0–12.0	. . .	0.10	. . .	. . .
S30415	. . .	0.04–0.06	0.80	0.045	0.030	1.00–2.00	18.0–19.0	9.0–10.0	. . .	0.12–0.18	. . .	Ce 0.03–0.08
S30441	. . .	0.08	2.0	0.045	0.030	1.0–2.0	17.5–19.5	8.010.5	. . .	0.10	1.5–2.5	Nb 0.1–0.5 W 0.2–0.8
S30451	304N	0.08	2.00	0.045	0.030	0.75	18.0–20.0	8.0–10.5	. . .	0.10–0.16	. . .	. . .
S30453	304LN	0.030	2.00	0.045	0.030	0.75	18.0–20.0	8.0–12.0	. . .	0.10–0.16	. . .	. . .
S31600	316	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	. . .	. . .
S31603	316L	0.030	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	. . .	. . .
S31635	316Ti[G]	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	. . .	Ti 5 × (C + N) min, 0.70 max
S31640	316Cb[G]	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	. . .	Nb 10 × C min, 1.10 max
S31651	316N	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10–0.16	. . .	. . .
S31653	316LN	0.030	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10–0.16	. . .	. . .
S31700	317	0.08	2.00	0.045	0.030	0.75	18.0–20.0	11.0–15.0	3.0–4.0	0.10	. . .	. . .
S31703	317L	0.030	2.00	0.045	0.030	0.75	18.0–20.0	11.0–15.0	3.0–4.0	0.10	. . .	. . .
S31725	317LM	0.030	2.00	0.045	0.030	0.75	18.0–20.0	13.5–17.5	4.0–5.0	0.20	. . .	. . .
S31726	317LMN[G]	0.030	2.00	0.045	0.030	0.75	17.0–20.0	13.5–17.5	4.0–5.0	0.10–0.20	. . .	. . .
S31727	. . .	0.030	1.00	0.030	0.030	1.00	17.5–1930	15.5–16.5	3.8–4.5	0.15–0.21	2.80–4.00	. . .
S31753	317LN[G]	0.030	2.00	0.045	0.030	0.75	18.0–20.0	11.0–15.0	3.0–4.0	0.10–0.22	. . .	. . .
Ferritic and Martensitic Stainless Steel												
S41000	410	0.15	1.00	0.040	0.030	1.00	11.5–13.5	. . .	. . .	. . .	. . .	. . .
S43000	430	0.12	1.00	0.040	0.030	1.00	16.0–18.0	. . .	. . .	. . .	. . .	. . .
S40900	409	0.08	1.00	0.045	0.030	1.00	10.5–11.7	0.50	. . .	. . .	. . .	Ti 6 × C min; 0.75 max
S43035	. . .	0.07	1.00	0.040	0.030	1.00	17.00–19.00	0.50	. . .	. . .	. . .	Al 0.15 Ni 0.04 Ti 0.20 + 4(C + N) min; 1.10 max
S44627[I]	XM-27	0.01	0.40	0.02	0.02	0.40	25.0–27.5	0.5[H]	0.75–1.50	0.015	0.2	Nb 0.05–0.20
S44400	18Cr-2Mo	0.025	1.00	0.040	0.030	1.00	17.5–19.5	1.00	1.75–2.50	0.035	. . .	(Ti + Nb) 0.20 + 4 (C + N) min; 0.80 max
S44700[J]	29-4	0.010	0.30	0.025	0.020	0.20	28.0–30.0	0.15	3.5–4.2	0.020	0.15	. . .
S44800[J]	29-4-2	0.010	0.30	0.025	0.020	0.20	28.0–30.0	2.0–2.5	3.5–4.2	0.020	0.15	. . .
S44660	26-3-3	0.030	1.00	0.040	0.030	1.00	25.0–28.0	1.0–3.50	3.0–4.0	0.040	. . .	(Ti + Nb) 0.20–1.00 and 6 × (C + N) min
S43940	. . .	0.03	1.00	0.040	0.015	1.00	17.5–18.50	. . .	. . .	. . .	. . .	Ti 0.10–0.60 Nb (3x%C + 0.30) min
Duplex Stainless Steel												
S31803	. . .	0.030	2.00	0.030	0.020	1.00	21.0–23.0	4.5–6.5	2.5–3.5	0.08–0.20	. . .	. . .
S32001	. . .	0.030	4.00–6.00	0.040	0.030	1.00	19.5–21.5	1.0–3.0	0.60	0.045–0.17	1.00	. . .
S32003	. . .	0.030	2.00	0.030	0.020	1.00	19.5–22.5	3.0–4.0	1.50–2.00	0.14–0.20	. . .	. . .
S32101	. . .	0.040	4.0–6.0	0.040	0.030	1.00	21.0–22.0	1.35–1.70	0.10–0.80	0.20–0.25	0.10–0.80	. . .
S32205	2205[G]	0.030	2.00	0.030	0.020	1.00	22.0–23.0	4.5–6.5	3.0–3.5	0.14–0.20	. . .	. . .
S32550	255[G]	0.04	1.50	0.040	0.030	1.00	24.0–27.0	4.5–6.5	2.9–3.9	0.10–0.25	1.50–2.50	. . .
S32750[K]	2507[G]	0.030	1.20	0.035	0.020	0.80	24.0–26.0	6.8–8.0	3.0–5.0	0.24–0.32	0.50	. . .
S32760[L]	. . .	0.030	1.00	0.030	0.010	1.00	24.0–26.0	6.0–8.0	3.0–4.0	0.20–0.30	0.50–1.00	W 0.50–1.00
S82441	. . .	0.030	2.50–4.00	0.035	0.005	0.70	23.0–25.0	3.0–4.5	1.00–2.00	0.20–0.30	0.10–0.80	. . .

[A]Maximum unless range or minimum is indicated.
[B]Designation established in accordance with Practice E527 and SAE J1086.

[C]Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).
[D]Carbon analysis shall be reported to nearest 0.01 % except for the low-carbon types, which shall be reported to nearest 0.001 %.
[E]The element columbium and its chemical symbol (Cb) are equivalent to the element niobium and its chemical symbol Nb.
[F]When two minimums or two maximums are listed for a single type, as in the case of both a value from a formula and an absolute value; the higher minimum or lower maximum shall apply.
[G]Common name, not a trademark, widely used, not associated with any one producer.
[H]Nickel plus Copper.
[I]For small diameter or thin walls, or both, tubing, where many drawing passes are required, a carbon maximum of 0.015 % is necessary. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.045 in. [1.2 mm] in average wall thickness (0.040 in. [1 mm] in minimum wall thickness).
[J]Carbon plus nitrogen = 0.025 % max.
[K] %C + 3.3 × %Mo + 16 × %N ≥ 41.
[L] %C + 3.3 × %Mo + 16 × %N ≥ 40.

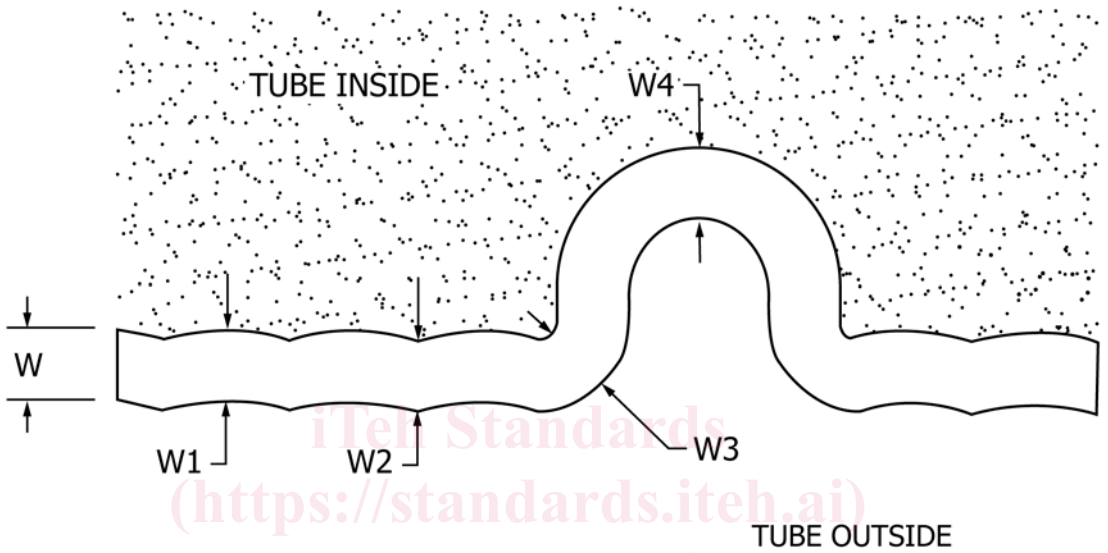


FIG. 3 Details Regarding the Wall Thickness of the Representative Sample Geometry of the Patterns Used to Texture the Flat Strip Material before It is Used to Create a Welded Tube

8.5 For duplex stainless steels, all tubes shall be furnished in the heat treated condition in accordance with the procedures shown in Table 2.

9. Product Analysis

9.1 If specified in the purchase order an analysis of the strip supplied from the material producer will be provided to the purchaser of the tube; however, if specified as a requirement, an analysis of either one length of flat-rolled stock or one tube shall be made for each heat. The chemical composition thus determined shall conform to the requirements given in Section 7 and Table 1.

9.2 A product analysis tolerance of Table A1.1 in Specification A480/A480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04 % or less.

9.3 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 (refer to Section 18 and Table 3) 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 that do not meet the requirements of this specification shall be rejected.

9.4 Any tests that are specified and required are performed on textured lengths of the tube in accordance with this specification need not be performed on both the textured and the plain sections of the tube.

10. Tensile Requirements

10.1 All portions of the tubes shall conform to the tensile requirements as stated in Table 4.

10.2 For calculating the mechanical properties, the cross-section to be used is calculated from the wall thickness with no pattern.

11. Hardness Requirements

11.1 The tubes shall have a Rockwell hardness number not exceeding those in Table 4. These values will be evaluated in both the textured and untextured sections (if both are present). The evaluation method will follow the method prescribed in Specification A1016/A1016M.

11.2 Hardness values for the textured section will be determined using microindentation hardness values taken from the cross section.

12. Reverse-Bend Test Requirement

12.1 A section 4 in. [100 mm] minimum in length shall be split longitudinally 90° on each side of the weld. The sample

TABLE 2 Heat Treatment Requirements

Designation	Type	Temperature[A]	Cooling/ Testing Requirements
Austenitic (Chromium-Nickel) (Chromium-Nickel-Molybdenum)			
All Cr-Ni steels except the following:		1900°F [1040°C]	[B]
N08904	904L[D]	2000°F [1095°C]	[C]
S31727		1975 to 2155°F [1080 to 1180°C]	[C]
Ferritic Stainless Steel			
All Ferritic Stainless Steels		1200°F [650°C]	
Duplex Stainless Steel			
S31803		1870–2010°F [1020–1100°C]	[E]
S32001		1800–1950°F [982–1066°C]	[E]
S32003		1850–2050°F [1010–1120°C]	[E]
S32101		1870°F [1020°C] min	[C]
S32205		1870–2010°F [1020–1100°C]	[E]
S32550		1900°F [1040°C]	[E]
S32750		1880–2060°F [1025–1125°C]	[E]
S32760		1960–2085°F [1070–1140°C]	[E]
S82441		1830°F [1000°C] min	[E]

[A]Minimum unless otherwise indicated.
[B]Quenched in water or rapidly cooled by other means at a rate sufficient to prevent reprecipitation of carbides as demonstrable by the capability of passing the test for resistance to intergranular corrosion specified in S7.
[C]Quenched in water or rapidly cooled by other means.
[D]Common name, not a trademark widely used, not associated with any one producer.
[E]Rapid cooling in air or water.

TABLE 3 Number of Tubes in a Lot Heat Treated by the Continuous Process

Size of Tube	Size of Lot
Less than or equal to 1.5 in. [38 mm] but over 1 in. [25 mm] in outside diameter or over 1 in. [25 mm] in outside diameter and under or equal to 0.079 in. [2 mm] in wall thickness	Not more than 75 tubes
1 in. [25 mm] or less in outside diameter	Not more than 125 tubes

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 areas 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. [100 mm] of weld is subjected to reverse bending.

13. Dimensions, Mass, and Permissible Variations

13.1 *Diameter*—The outside diameter of the untextured or textured sections shall be measured by flat anvil micrometers or equivalent, such as laser micrometer, unless otherwise agreed upon between the producer and the customer.

13.2 *Wall Thickness*—The starting material strip wall thickness shall conform to the requirements for tube wall thickness prescribed in accordance with Specification A1016/A1016M. Wall thickness tolerances shall be ±10 % of specified wall for all tubing sizes or other agreed tolerance variation values agreed between the producer and the customer. Strip material may be redistributed, but material may not be removed from the surface by any method.

13.2.1 The wall thickness (Fig. 3: W, W1-W4) of textured and untextured sections of the tube shall not exceed the thickness tolerances shown in Specification A1016/A1016M unless otherwise agreed to between the manufacturer and purchaser. No tube wall thickness at any point shall be less than the minimum thickness requirements for wall thickness, prescribed in Specification A1016/A1016M which is specified for the plain sections or in the textured sections unless customer and manufacturer agree after evaluating test data of similarly produced textured tubes.

13.3 *Alternative Methods:*

13.3.1 Wall thickness shall be evaluated using any instrument (that is, pointing micrometer, optical, microscopic, and so forth) that is capable of satisfying the required accuracy. Testing frequency shall be one tube per lot for lots as described in Table 3. Alternative methods of measurement able to measure the OD and wall include electronic micrometers, a no-go snap gauge, ring gauge, non-contact profilometers or optical methods with the same tolerance and accuracy.

NOTE 1—Plan cylindrical ring gauges are used to check the outside diameter limit on manufactured parts.

13.4 *Length*—The length of the tubes shall not be less than that specified in the purchase order.

13.4.1 The length of plain ends, as measured from the tube end to the first textured character, shall not be less than that specified but may exceed the specified value by 0.5 in. [13 mm].

13.4.2 The length of textured sections and untextured portions shall be as specified; ±0.25 in. [6 mm].

13.5 *Squareness of Cut*—The angle of the cut of the end of any tube may depart from square by not more than 0.016 in. [0.4 mm].

13.6 *Straightness*—The tube shall be reasonably straight and free of bends or kinks.

14. Workmanship, Finish, and Appearance

14.1 Finished tubes shall have smooth ends free of burrs and shall not deviate from straightness by more than 0.030 in. [0.8 mm] in 3 ft [900 mm] on length.

15. Mechanical Tests Required

15.1 *Tension Test*—One tension test shall be made on a specimen for size of lots described in Section 18 and Table 3.

15.2 *Flattening Test*—One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flange test, from each lot (refer to Table 3).

15.3 *Flange Test*—One flange test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (refer to Table 3).

TABLE 4 Mechanical Test Requirements

Austenitic Stainless Steel								
UNS Designation	Type[A]	Tensile Strength, min		Yield Strength, min[B]		Elongation[C] in 50 mm or 2 in., min, %	Hardness, max[D]	
		MPa	ksi	MPa	ksi		Brinell, HBW	Rockwell B
N08904	904L[E]	490	71	220	31	35	. . .	90
S30103	301L[E]	550	80	220	32	45	217	95
S30153	301LN[E]	550	80	240	35	45	217	95
S30200	302	515	75	205	30	40	201	92
S30400	304	515	75	205	30	40	201	92
S30403	304L	485	70	170	25	40	201	92
S30415	. . .	600	87	290	42	40	217	95
S30441	. . .	515	75	205	30	40	201	92
S30451	304N	550	80	240	35	30	217	95
S30453	304LN	515	75	205	30	40	217	95
S31600	316	515	75	205	30	40	217	95
S31603	316L	485	70	170	25	40	217	95
S31635	316Ti[E]	515	75	205	30	40	217	95
S31640	316Cb[E]	515	75	205	30	30	217	95
S31651	316N	550	80	240	35	35	217	95
S31653	316LN	515	75	205	30	40	217	95
S31700	317	515	75	205	30	35	217	95
S31703	317L	515	75	205	30	40	217	95
S31725	317LM[E]	515	75	205	30	40	217	95
S31726	317LMN[E]	550	80	240	35	40	217	95
S31727	. . .	550	80	245	36	35	217	95
S31753	317LN	550	80	240	35	40	217	95
Ferritic and Martensitic Stainless Steel								
UNS Designation	Type[A]	Tensile Strength, min		Yield Strength, min[B]		Elongation[F] in 50 mm or 2 in., min, %	Hardness, max	
		MPa	ksi	MPa	ksi		Brinell, HBW	Rockwell B
S41000	TP410	415	60	205	30	20	. . .	. . .
S43000	TP430	415	60	240	35	20	. . .	. . .
S40900	TP409	380	55	170	25	20	. . .	. . .
S43035	TP439	415	60	205	30	20	. . .	. . .
S44627	TPXM-27	450	65	275	40	20	. . .	. . .
S44400	18Cr-2Mo	415	60	275	40	20	. . .	. . .
S44700	29-4	550	80	415	60	20	. . .	. . .
S44800	29-4-2	550	80	415	60	20	. . .	. . .
S44660	26-3-3	585	85	450	65	20	. . .	. . .
S43940	. . .	430	62	250	36	18	. . .	. . .
Duplex Stainless Steel								
UNS Designation	Type[A]	Tensile Strength, min		Yield Strength, min[B]		Elongation[C] in 50 mm or 2 in., min, %	Hardness, max[D]	
		MPa	ksi	MPa	ksi		HBW	HRC
S31803	. . .	620	90	450	65	25	290	30
S32001	. . .	620	90	450	65	25	290	30
S32003[G]								
Wall ≤ 0.187 in. [5.00 mm]	. . .	690	100	485	70	25	290	30
Wall > 0.187 in. [5.00 mm]	. . .	655	95	450	65	25	290	30
S32101								
Wall ≤ 0.187 in. [5 mm]	. . .	700	101	530	77	30	290	30
Wall > 0.187 in. [5 mm]	. . .	650	94	450	65	30	290	30
S32205	2205[E]	655	95	485	70	25	290	30
S32550	255[E]	760	110	550	80	15	297	31
S32750	2507[E]	800	116	550	80	15	300	32
S32760	. . .	750	109	550	80	25	310	32
S82441								
Wall 0.40 in. [10 mm] and above	. . .	680	99	480	70	25	290	30
Wall below 0.40 in. [10 mm]	. . .	740	109	540	78	25	290	30

[A]Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).
[B]Yield strength shall be determined by the offset method at 0.2 % in accordance with Test Method and Definitions A370. Unless otherwise specified (see Specification A480/A480M, Paragraph 4.1.11 Ordering Information), an alternative method of determining yield strength may be based on total extension under load of 0.5 %.
[C]Elongation for thickness, less than 0.38 mm [0.015 in.] shall be 20 % minimum, min 25.4 mm [1 in.].
[D]Either Brinell or Rockwell B Hardness is permissible.
[E]Common name, not a trademark, widely used, not associated with any one producer.
[F]For tubing smaller than 0.5 in. [12.7 mm] in outside diameter, the elongation values given for strip specimens in Table 2 shall apply. Mechanical property requirements do not apply to tubing smaller than 0.125 in. [3.2 mm] in outside diameter or with walls thinner than 0.015 in. [0.4 mm].
[G]Prior to A789/A789M – 04, the vales for S32003 were 90 ksi tensile strength and 65 ksi yield strength.