



Designation: A1098/A1098M – 16

# Standard Specification for Welded Austenitic Alloy Steel Boiler, Superheater, Condenser, and Heat Exchanger Tubes with Textured Surface(s)<sup>1</sup>

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 ( $\epsilon$ ) 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 alloy 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  $\frac{3}{8}$  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 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.

1.5 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 and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

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

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

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

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

### 2.2 ASME Standard:<sup>3</sup>

Boiler and Pressure Vessel Code Section VIII Para UW-51

### 2.3 SAE Standards:<sup>4</sup>

SAE J1086 Practice for Numbering Metals and Alloys (UNS)

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

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

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

<sup>1</sup> 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 Nov. 15, 2016. Published January 2017. DOI: 10.1520/A1098\_A1098M-16.

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)

3.3.21  $W_2$ —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.

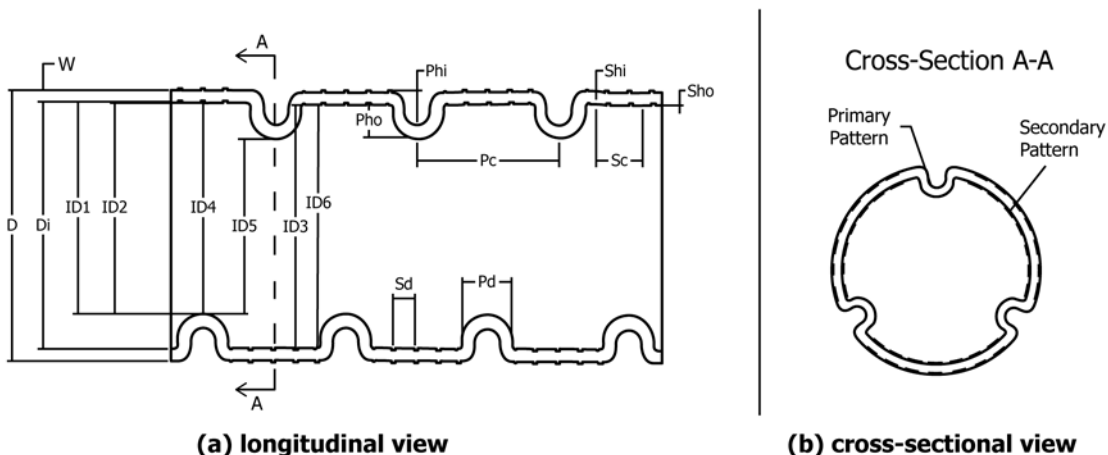
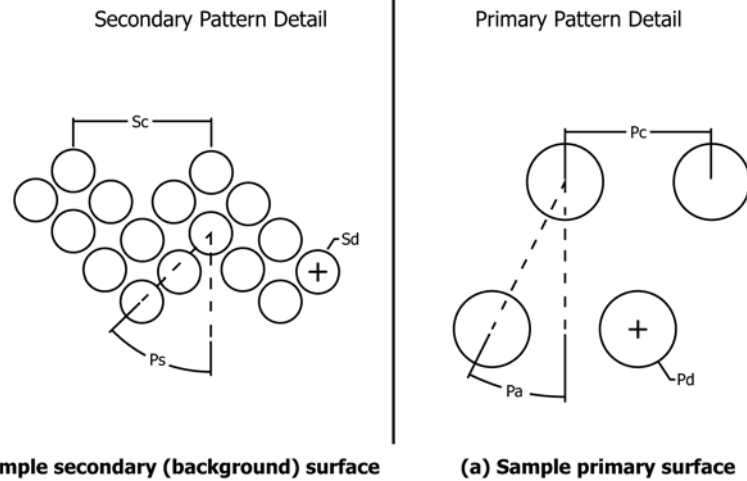


FIG. 1 Views of a Representative Textured Tube Showing Variables that Describe the Possible Primary and Secondary Texturizations that May be Applied to the Inside Surface of a Tube, Outside Surface of the Tube, or Both the Inside and Outside Surfaces of the Tube



**(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**

**TABLE 1 Chemical Composition Requirements, %<sup>A</sup>**

UNS Designation <sup>B</sup>	Type <sup>C</sup>	Carbon <sup>D</sup>	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen	Copper	Other Elements <sup>E,F</sup>
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 <sup>G</sup>	0.03	2.00	0.045	0.030	1.00	16.0–18.0	6.0–8.0	...	0.20	...	...
S30153	301LN <sup>G</sup>	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
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	0.03–0.08 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 <sup>G</sup>	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 <sup>G</sup>	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 × 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	317LM <sup>G</sup> N	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	17.5–19.30	15.5–16.5	3.8–4.5	0.15–0.21	2.80–4.00	...
S31753	317LN <sup>G</sup>	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	...	...

<sup>A</sup>Maximum unless range or minimum is indicated.

<sup>B</sup>Designation established in accordance with Practice E527 and SAE J1086.

<sup>C</sup>Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).

<sup>D</sup>Carbon analysis shall be reported to nearest 0.01 % except for the low-carbon types, which shall be reported to nearest 0.001 %.

<sup>E</sup>The element columbium and its chemical symbol (Cb) are equivalent to the element niobium and its chemical symbol Nb.

<sup>F</sup>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.

<sup>G</sup>Common name, not a trademark, widely used, not associated with any one producer.

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

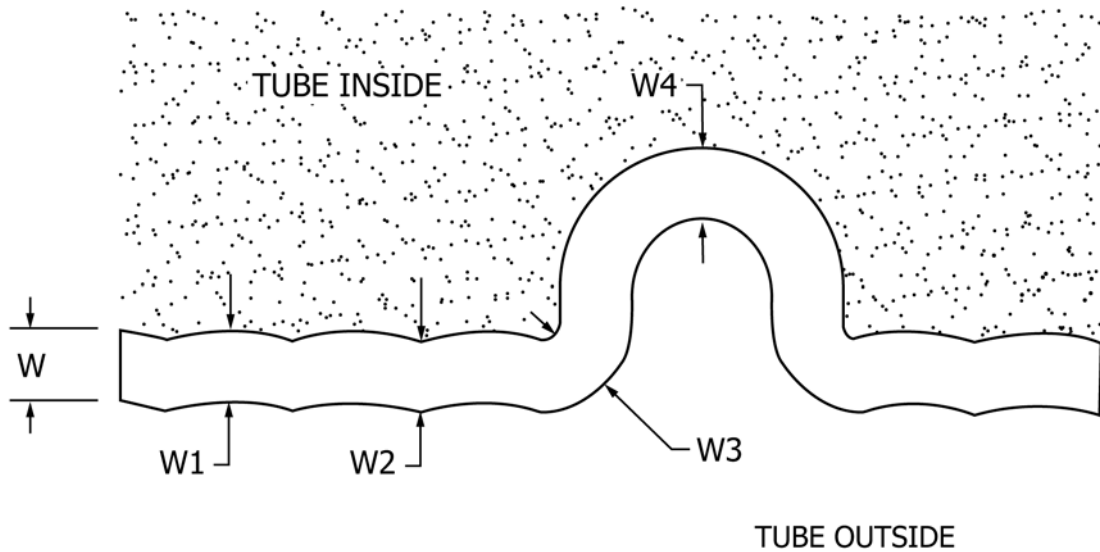


FIG. 3 Details Regarding the Wall Thickness of the Representative Sample Geometry of the Patterns Used to Texture the Flat Strip Material before It is Used to Create a Welded Tube

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 Tubes shall be provided in the solution annealed condition as specified 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

TABLE 2 Heat Treatment Requirements

Designation/Type	Temperature <sup>A</sup>	Cooling/Testing Requirements
Austenitic (Chromium-Nickel) (Chromium-Nickel-Molybdenum)		
All Cr-Ni steels except the following:	1900°F [1040°C]	<sup>B</sup>
N08904	2000°F [1095°C]	<sup>C</sup>
S31727	1975 to 2155°F [1080 to 1180°C]	<sup>C</sup>

<sup>A</sup>Minimum unless otherwise indicated.

<sup>B</sup>Quenched in water or rapidly cooled by other means at a rate sufficient to prevent precipitation of carbides as demonstrable by the capability of passing the test for resistance to intergranular corrosion specified in S7.

<sup>C</sup>Quenched in water or rapidly cooled by other means.

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

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