Designation: A249/A249M – 16a

Used in USDOE-NE Standards

Standard Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes[1]

This standard is issued under the fixed designation A249/A249M; 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 nominal-wall-thickness welded tubes and heavily cold worked welded tubes made from the austenitic steels listed in Table 1, with various grades intended for such use as boiler, superheater, heat exchanger, or condenser tubes.

1.2 Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP309S, TP309Cb, TP310S, TP310Cb, TP316, TP321, TP347, and TP348, and are intended for high-temperature service such as for superheaters and reheaters.

1.3 The tubing sizes and thicknesses usually furnished to this specification are ⅛ in. [3.2 mm] in inside diameter to 12 in. [304.8 mm] in outside diameter and 0.015 to 0.320 in. [0.4 to 8.1 mm], inclusive, in wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.4 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

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

1.6 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.

1.7 The following safety hazards caveat pertains only to the test method described in the Supplementary Requirements of this specification. *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.* A specific warning statement is given in Supplementary Requirement S7, Note S7.1.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

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

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

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

E112 Test Methods for Determining Average Grain Size

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E273 Practice for Ultrasonic Testing of the Weld Zone of Welded Pipe and Tubing

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

2.2 *ASME Boiler and Pressure Vessel Code:*

Section VIII [4]

2.3 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[5]

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

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-249 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] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[5] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

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

TABLE 1 Chemical Requirements, %[A]

Grade	UNS Designation[B]	Composition, %										
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen[C]	Copper	Other
TP 201	S20100	0.15	5.50–7.5	0.060	0.030	1.00	16.0–18.0	3.5–5.5	...	0.25	...	...
TP 201LN	S20153	0.03	6.4–7.5	0.045	0.015	0.75	16.0–17.5	4.0–5.0	...	0.10–0.25	1.00	...
TP 202	S20200	0.15	7.5–10.0	0.060	0.030	1.00	17.0–19.0	4.0–6.0	...	0.25	...	...
TPXM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	0.20–0.40	...	Nb[G] 0.10–0.30 V 0.10–0.30
TPXM-29	S24000	0.08	11.5–14.5	0.060	0.030	1.00	17.0–19.0	2.3–3.7	...	0.20–0.40	...	...
TP304	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...
TP304L[D]	S30403	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	...	...	...	...
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...
...	S30415	0.04–0.06	0.80	0.045	0.030	1.00–2.00	18.0–19.0	9.0–10.	...	0.12–0.18	...	Ce 0.03–0.08
TP304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	0.10–0.16	...	...
TP304LN[D]	S30453	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	0.10–0.16	...	...
TP305	S30500	0.12	2.00	0.045	0.030	1.00	17.0–19.0	11.0–13.0	...	...	...	...
...	S30615	0.16–0.24	2.00	0.030	0.030	3.2–4.0	17.0–19.5	13.5–16.0	...	...	...	...
...	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	...	0.14–0.20	...	Ce 0.03–0.08
TP309S	S30908	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	...	...	...	...
TP309H	S30909	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	...	...	...	...
...	S30601	0.015	0.50–0.80	0.030	0.013	5.0–5.6	17.0–18.0	17.0–18.0	0.20	0.05	0.35	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	...	...	...	Nb 10x C-1.10
TP309HCb	S30941	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	...	...	...	Nb 10x C-1.10
TP310S	S31008	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...	...
TP310H	S31009	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...	...
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00	24.0–26.0	18.0–22.0	...	...	...	Nb 10x C-1.10
TP310HCb	S31041	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...	Nb 10x C-1.10
...	S31050	0.030	2.00	0.030	0.015	0.40	24.0–26.0	21.0–23.0	2.00–3.00	0.10–0.16	...	...
...	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	0.18–0.25	0.50–1.00	...
...	S31266	0.030	2.00–4.00	0.035	0.020	1.00	23.0–25.0	21.0–24.0	5.2–6.2	0.35–0.60	1.00–2.50	W 1.50–2.50
...	S31277	0.020	3.00	0.030	0.010	0.50	20.5–23.0	26.0–28.0	6.5–8.0	0.30–0.40	0.50–1.50	...
TP316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...
TP316L[D]	S31603	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...
TP316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	0.10–0.16	...	...
TP316LN[D]	S31653	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	0.10–0.16	...	...
	S31655	0.030	2.00	0.045	0.015	1.00	19.5–21.5	8.0–9.5	0.50–1.50	0.14–0.25	1.00	...
TP317	S31700	0.08	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...	...
TP317L	S31703	0.030	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...	...
...	S31725	0.030	2.00	0.045	0.030	1.00	18.0–20.0	13.5–17.5	4.0–5.0	0.20	...	...
...	S31726	0.030	2.00	0.045	0.030	1.00	17.0–20.0	14.5–17.5	4.0–5.0	0.10–0.20	...	...
...	S31727	0.030	1.00	0.030	0.030	1.00	17.5–19.0	14.5–16.5	3.8–4.5	0.15–0.21	2.8–4.0	...
...	S32050	0.030	1.50	0.035	0.020	1.00	22.0–24.0	20.0–23.0	6.0–6.8	0.21–0.32	0.40	...

TABLE 1 *Continued*

...	S32053	0.030	1.00	0.030	0.010	1.00	22.0–24.0	24.0–26.0	5.0–6.0	0.17–0.22	...	...
TP321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	0.10	...	Ti 5(C+N)-0.70
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	0.10	...	Ti 5(C+N)-0.70
...	S32615	0.07	2.00	0.045	0.030	4.80–6.00	16.5–19.5	19.0–22.0	0.30–1.50	...	1.50–2.50	...
...	S32654	0.020	2.0–4.0	0.030	0.005	0.50	24.0–25.0	21.0–23.0	7.0–8.0	0.45–0.55	0.30–0.60	...
...	S33228	0.04–0.08	1.00	0.020	0.015	0.30	26.0–28.0	31.0–333.0	...	...	...	Nb 0.60–1.00 Ce 0.05–0.10 Al0.025
...	S34565	0.030	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	0.40–0.60	...	Nb 0.10
TP347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	Nb 10xC-1.10
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	Nb 8xC-1.10
TP348	S34800	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	(Nb+Ta) 10xC-1.10 Ta 0.10 Co 0.20
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	(Nb+Ta) 8xC-1.10 Ta 0.10 Co 0.20
...	S35045	0.06–0.10	1.50	0.045	0.015	1.00	25.0–29.0	32.0–37.0	...	...	0.75	Al 0.15–0.60 Ti 0.15–0.60
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.0–19.0	17.5–18.5	...	...	...	...
...	S38815	0.030	2.00	0.040	0.020	5.5–6.5	13.0–15.0	15.0–17.0	0.75–1.50	...	0.75–1.50	Al 0.30 max
Alloy 20	N08020	0.070	2.00	0.045	0.035	1.00	19.0–21.0	32.0–38.0	2.00–3.00	...	3.00–4.00	Nb 8 × C min. to 1.00 max
...	N08367	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	6.0–7.0	0.18–0.25	0.75	...
800	N08800	0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...	0.75	Al 0.15–0.60 Ti 0.15–0.60 Fe[E] 39.5 min
800H	N08810	0.05–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...	0.75	Al 0.15–0.60 Ti 0.15–0.60 Fe[E] 39.5 min

TABLE 1 *Continued*

...	N08811	0.05–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	...	...	0.75	Al 0.25–0.60[F] Ti 0.25–0.60[F] Fe[E] 39.5 min
...	N08926	0.020	2.00	0.030	0.010	0.50	19.0–21.0	24.0–26.0	6.0–7.0	0.15–0.25	0.50–1.50	...
...	N08904	0.020	2.00	0.040	0.030	1.00	19.0–23.0	23.0–28.0	4.0–5.0	0.10	1.00–2.00	...

[A] Maximum, unless otherwise indicated.
[B] New designation established in accordance with Practice E527 and SAE J1086.
[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
[D] For small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in Grades TP 304L and TP 316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall are those less than 0.049 in. [1.2 mm] in minimum wall thickness.
[E] Iron shall be determined arithmetically by difference of 100 minus the sum of the other specified elements.
[F] (Al + Ti) = 0.85 to 1.20.
[G] The term Niobium (Nb) and Columbium (Cb) are alternate names for the same element.

3. Ordering Information

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

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

3.1.2 Name of material welded tubes (WLD) or heavily cold worked tubes (HCW),

3.1.3 Grade (Table 1),

3.1.4 Size (outside diameter and nominal wall thickness),

3.1.5 Length (specific or random),

3.1.6 Optional requirements (13.6),

3.1.7 Test report required (see Certification Section of Specification A1016/A1016M),

3.1.8 Specification designation, and

3.1.9 Special requirements and any supplementary requirements selected.

3.1.9.1 If Supplementary Requirement S7 is specified, include weld decay ratio per S11.1.1.

4. General Requirements

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

5. Manufacture

5.1 The welded (WLD) tubes shall be made from flat-rolled steel by an automatic welding process with no addition of filler metal.

5.1.1 Subsequent to welding and prior to final heat treatment, the tubes shall be cold worked either in both weld and base metal or in weld metal only. The method of cold working may be specified by the purchaser. When cold drawn, the purchaser may specify the minimum amount of reduction in cross-sectional area or wall thickness, or both.

5.1.2 Heavily cold worked (HCW) tubes shall be made by applying cold working of not less than 35 % reduction in both wall and weld to a welded tube prior to the final anneal. No filler metal shall be used in the making of the weld. Prior to cold working, the weld shall be 100 % radiographically inspected in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest revision, Paragraph UW 51.

6. Heat Treatment

6.1 All material shall be furnished in the heat-treated condition in accordance with the requirements of Table 2.

6.2 A solution annealing temperature above 1950 °F [1065 °C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S4).

6.3 N08020 shall be supplied in the stabilization treatment condition.

7. Chemical Composition

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

8. Product Analysis

8.1 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.

8.2 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.

8.3 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 (See 13.9.1) 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 the specification shall be rejected.

9. Tensile Requirements

9.1 The material shall conform to the tensile properties prescribed in Table 3.

10. Hardness Requirements

10.1 The tubes shall have a Rockwell hardness number not exceeding the values specified in Table 3.

11. Reverse-Bend Test Requirement

11.1 A section 4 in. [100 mm] minimum in length shall be split longitudinally 90° on each side of the weld. The sample shall then be opened and bent around a mandrel with a maximum thickness of four times the wall thickness, with the mandrel parallel to the weld and against the original outside surface of the tube. The weld shall be at the point of maximum bend. There shall be no evidence of cracks, or of overlaps resulting from the reduction in thickness of the weld 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. of weld is subjected to reverse bending.

NOTE 1—The reverse bend test is not applicable when the specified wall is 10 % or more of the specified outside diameter, or the wall thickness is 0.134 in. [3.4 mm] or greater, or the outside diameter size is less than 0.375 in. [9.5 mm]. Under these conditions the reverse flattening test of Specification A1016/A1016M shall apply.

12. Grain Size Requirement

12.1 The grain size of Grades TP309H, TP309HCb, TP310H and TP310HCb, as determined in accordance with Test Methods E112, shall be No. 6 or coarser.

12.2 The grain size of Grades TP304H, TP316H, TP321H, TP347H and TP348H, as determined in accordance with Test Methods E112, shall be No. 7 or coarser.

TABLE 2 Heat Treatment Requirements

Grade	UNS Number	Solutioning Temperature, min or range	Quenching Method
All grades not individually listed below		1900 °F [1040 °C]	[A]
...	S30601	2010 to 2140 °F [1100 to 1170 °C]	[B]
...	S30815	1920 °F [1050 °C]	[B]
TP309HCb	S30941	1900 °F [1040 °C][C]	[B]
TP310H	S31009	1900 °F [1040 °C]	[B]
TP310HCb	S31041	1900 °F [1040 °C][C]	[B]
...	S31254	2100 °F [1150 °C]	[B]
...	S31266	2100 °F [1150 °C]	[B]
...	S31277	2050 °F [1120 °C]	[B]
TP316H	S31609	1900 °F [1040 °C]	[B]
...	S31727	1975 °F [1080 °C]–	[B]
		2155 °F [1180 °C]	[B]
...	S32053	1975 °F [1080 °C]–	[B]
		2155 °F [1180 °C]	[B]
TP321	S32100	1900 °F [1040 °C][C]	[B]
TP321H	S32109	2000 °F [1100 °C][C]	[B]
...	S32654	2100 °F [1150 °C]	[B]
...	S33228	2050 °F [1120 °C]	[B]
...	S34565	2050 °F [1120 °C]–	[B]
		2140 °F [1170 °C]	[B]
TP347	S34700	1900 °F [1040 °C][C]	[B]
TP347H	S34709	2000 °F [1100 °C][C]	[B]
TP348	S34800	1900 °F [1040 °C][C]	[B]
TP348H	S34809	2000 °F [1100 °C][C]	[B]
...	S35045	2000 °F [1100 °C]	[D]
...	S38815	1950 °F [1065 °C]	[B]
Alloy 20	N08020	1700–1850 °F [925–1010 °C] stabilization treatment	[B]
...	N08367	2025 °F [1110 °C]	[B]
800	N08800	1900 °F [1040 °C]	[B]
800H	N08810	2050 °F [1120 °C]	[B]
...	N08811	2100 °F [1150 °C]	[B]
...	N08904	2000 °F [1100 °C]	[B]
...	N08926	2010 °F [1105 °C]	[B]

[A] Quenched in water or rapidly cooled by other methods, at a rate sufficient to prevent reprecipitation of chromium carbides, as demonstrated by the capability of passing Practices A262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (See Supplementary Requirement S6). Note that Practices A262 requires the test to be performed on sensitized specimens in the low carbon and stabilized types and on specimens representative of the as-shipped condition of the other types. In the case of low-carbon types containing 3 % or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and purchaser.
[B] Quenched in water or rapidly cooled by other methods.
[C] A solution treating temperature above 1950 °F [1065 °C] may impair resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in the indicated grades. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the higher-temperature solution anneal prescribed in this table (See Supplementary Requirement S4).
[D] Cooled in still air, or faster.

12.3 The grain size of Grade UNS S32615, as determined in accordance with Test Methods E112, shall be No. 3 or finer.

12.4 The grain size of N08810 and N08811, as determined in accordance with Test Methods E112, shall be 5 or coarser.

13. Mechanical Tests and Grain Size Determinations Required

13.1 *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 (See 13.9.2).

13.2 *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 (See 13.9.1).

13.3 *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 (See 13.9.1).

13.4 *Reverse-Bend Test*—One reverse-bend test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

13.5 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (See 13.9.2).

13.6 *Hydrostatic or Nondestructive Electric Test*—Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

13.7 *Grain Size*—Grain size determinations on grades TP309H, TP309HCb, TP310H and TP310HCb shall be made on the same number of tubes as prescribed for the flattening test.

13.8 Heavily cold worked tubes (HCW) shall be capable of passing the weld decay test listed in Supplementary S7 with a weld metal to base metal loss ratio of 0.90 to 1.10. The test is not required unless S7 is specified in the purchase order.

13.9 *Lot Definitions:*

13.9.1 For flattening and flange requirements, the term lot applies to all tubes prior to cutting of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot

TABLE 3 Tensile and Hardness Requirements[A]

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Rockwell Hardness Number, max
TP201	S20100	95 [655]	38 [260]	35	B95
TP 201LN	S20153	95 [655]	45 [310]	45	B100
TP202	S20200	90 [620]	38 [260]	35	B95
TPXM-19	S20910	100 [690]	55 [380]	35	C25
TPXM-29	S24000	100 [690]	55 [380]	35	B100
TP304	S30400	75 [515]	30 [205]	35	B90
TP304L	S30403	70 [485]	25 [170]	35	B90
TP304H	S30409	75 [515]	30 [205]	35	B90
. . .	S30415	87 [600]	42 [290]	35	B96
TP304N	S30451	80 [550]	35 [240]	35	B90
TP304LN	S30453	75 [515]	30 [205]	35	B90
TP305	S30500	75 [515]	30 [205]	35	B90
...	S30601	78 [540]	37 [255]	30	B100
...	S32615	80 [550]	32 [220]	25	B100
...	S30615	90 [620]	40 [275]	35	B95
...	S30815	87 [600]	45 [310]	35	B95
TP309S	S30908	75 [515]	30 [205]	35	B90
TP309H	S30909	75 [515]	30 [205]	35	B90
TP309Cb	S30940	75 [515]	30 [205]	35	B90
TP309HCb	S30941	75 [515]	30 [205]	35	B90
TP310S	S31008	75 [515]	30 [205]	35	B90
TP310H	S31009	75 [515]	30 [205]	35	B90
TP310Cb	S31040	75 [515]	30 [205]	35	B90
TP310HCb	S31041	75 [515]	30 [205]	35	B90
...	S31050:				
	t ≤ 0.25 in.	84 [580]	39 [270]	25	B95
	t > 0.25 in.	78 [540]	37 [255]	25	B95
...	S31254:				
	t ≤ 0.187 in. [5.00 mm]	98 [675]	45 [310]	35	B100
	t > 0.187 in. [5.00 mm]	95 [655]	45 [300]	35	B100
...	S31266	109 [750]	61 [420]	35	B100
...	S31277	112 [770]	52 [360]	40	B100
TP316	S31600	75 [515]	30 [205]	35	B90
TP316L	S31603	70 [485]	25 [170]	35	B90
TP316H	S31609	75 [515]	30 [205]	35	B90
TP316N	S31651	80 [550]	35 [240]	35	B90
TP316LN	S31653	75 [515]	30 [205]	35	B90
	S31655	92 [635]	45 [310]	35	B100
TP317	S31700	75 [515]	30 [205]	35	B90
TP317L	S31703	75 [515]	30 [205]	35	B90
...	S31725	75 [515]	30 [205]	35	B90
...	S31726	80 [550]	35 [240]	35	B90
...	S31727	80 [550]	36 [245]	35	B96
...	S32050	98 [675]	48 [330]	40	
...	S32053	93 [640]	43 [295]	40	B96
TP321	S32100	75 [515]	30 [205]	35	B90
TP321H	S32109	75 [515]	30 [205]	35	B90
. . .	S32654	109 [750]	62 [430]	35	B100
...	S33228	73 [500]	27 [185]	30	B90
. . .	S34565	115 [795]	60 [415]	35	B100
TP347	S34700	75 [515]	30 [205]	35	B90
TP347H	S34709	75 [515]	30 [205]	35	B90
TP348	S34800	75 [515]	30 [205]	35	B90
TP348H	S34809	75 [515]	30 [205]	35	B90
...	S35045	70 [485]	25 [170]	35	B90
TPXM-15	S38100	75 [515]	30 [205]	35	B90
...	S38815	78 [540]	37 [255]	30	B100
Alloy 20	N08020	80 [550]	35 [240]	30	B95
...	N08367				
	t ≤ 0.187	100 [690]	45 [310]	30	B100
	t > 0.187	95 [655]	45 [310]	30	B100
800	N08800	75 [515]	30 [205]	30	90
800H	N08810	65 [450]	25 [170]	30	90
...	N08811	65 [450]	25 [170]	30	90
. . .	N08904	71 [490]	31 [215]	35	B90
. . .	N08926	94 [650]	43 [295]	35	B100

[A] Not applicable to tubes less than ⅛ in. [3.2 mm] in outside diameter or having wall thickness below 0.015 in. [0.4 mm], or both. The tensile properties of such small diameter or thin wall tubes shall be a matter of agreement between the manufacturer and the purchaser.

shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 4.

13.9.2 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, annealed in the same furnace at the same temperature, time at heat, and furnace speed.

14. Permissible Variations in Dimensions

14.1 Dimensional tolerances other than wall thickness tolerances shall be in accordance with Specification A1016/A1016M. Wall thickness tolerances shall be ±10 % of nominal wall for all tubing sizes.

14.2 The wall thickness of the weld shall not exceed the wall thickness measured 90° from the weld by more than 6 % of the specified wall thickness or 0.004 in. [0.1 mm], whichever is greater.

14.2.1 Requirements of 14.2 are not applicable when any of the following apply:

14.2.1.1 When the specified wall thickness exceeds 12 % of the specified outside diameter;

14.2.1.2 When the specified wall thickness exceeds 0.165 in. [4.2 mm];

14.2.1.3 When the specified OD exceeds 3 in. [76.2 mm]; or

14.2.1.4 When the specified minimum yield strength given in Table 3 for the specified grade is 35 ksi [240 MPa] or greater.

15. Workmanship, Finish, and Appearance

15.1 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] of length.

16. Surface Condition

16.1 The tubes, after final heat treatment, shall be chemically descaled or pickled free of scale. When bright annealing is used, pickling or chemical descaling is not necessary.

TABLE 4 Number of Tubes in a Lot Heat Treated by the Continuous Process

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

17. Forming Operations

17.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. All tubes, when properly manipulated, shall be able to stand expanding and beading without showing cracks and flaws, and also shall stand all forging, welding, and bending operations necessary for application without developing defects.

18. Product Marking

18.1 In addition to the marking prescribed in Specification A1016/A1016M, the marking for Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, TP348H, N08810, and N08811 shall also include the heat number and the heat-treatment lot identification.

19. Keywords

19.1 austenitic stainless steel; boiler tubes; condenser tube; heat exchanger tube; high temperature applications; N08800; N08810; N08811; steel tube; superheater tubes; temperature service applications, high; welded steel tube and heavily cold worked (HCW) tubes

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.

S1. Stress-Relieved Annealed Tubes

S1.1 For use in certain corrosives, particularly chlorides where stress corrosion may occur, tubes in Grades TP304L, TP316L, TP321, TP347, and TP348 may be specified in the stress-relieved annealed condition. Details of these supplemental requirements shall be agreed upon by the manufacturer and the purchaser.

S1.2 When stress-relieved tubes are specified, tubes shall be given a heat treatment at 1550 to 1650 °F [845 to 900 °C] after roll straightening. Cooling from this temperature range may be either in air or by slow cooling. No mechanical straightening is permitted after the stress-relief treatment.

S1.3 Straightness of the tubes shall be a matter of negotiation between the purchaser and manufacturer.

S2. Minimum Wall Tubes

S2.1 When specified by the purchaser, tubes shall be furnished on a minimum wall basis. Such tubes shall satisfy the minimum wall thickness requirements of Specification A1016/A1016M rather than the nominal wall requirements of this specification. In addition to the marking required by Section 18, the tubing shall be marked S2.

S3. Pneumatic Test

S3.1 The tubing shall be examined by a pneumatic test (either air under water or pneumatic leak test) in accordance with Specification A1016/A1016M.

S4. Stabilizing Heat Treatment

S4.1 Subsequent to the solution anneal required in Section 6, Grades TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S5. Unstraightened Tubes

S5.1 When the purchaser specifies tubes unstraightened after final heat treatment (such as coils), the straightness requirement of Section 12 shall not apply and the minimum yield strength of Table 4 shall be reduced by 5 ksi [35 MPa].

S5.2 On the certification, and wherever the grade designation for unstraightened tubing appears, it shall be identified with the suffix letter “U” (for example, 304-U, 321-U, etc.).

S6. Intergranular Corrosion Test

S6.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A262, Practice E.

NOTE S6.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S6.2 A stabilization heat treatment in accordance with Supplementary Requirement S4 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

S7. Weld Decay Test

S7.1 This test is not applicable to alloys with a nickel content ≥ 19.0 % or a molybdenum content ≥ 4.00 %, or both.

NOTE S7.1—The weld decay test is sensitive for the presence of delta ferrite in the weld material. Increasing amounts of delta ferrite will result in a higher ratio as defined in S7.10. Alloys with the high nickel or molybdenum content of S7.1 may not form delta ferrite and therefore may not be sensitive to this test.

S7.2 When specified by the purchase order, one sample from each lot of tubing (See 13.9.2) shall be subjected to testing in a boiling mixture of 50 % reagent grade hydrochloric acid and 50 % water.

S7.3 Approximately 2-in. long samples shall be prepared from a production length of tubing. Shorter, 1-in. samples may be used for small diameter (½-in. and below) tubing. Split the sample longitudinally to allow for easy micrometer measurements. The sample may be one piece which contains the weld and at least 90° of base-metal to one side of the weld.

Alternately, the sample may be two separate pieces with one containing the weld and a similar size section from the balance of the tube opposite the weld consisting of 100 % base metal. Remove all burrs and sharp edges by lightly grinding. Remove dust and grease by cleaning with soap and water or other suitable solvents. Then, place sample(s) in the flask. It is not recommended to test more than four samples together, or to mix alloy types.

S7.4 Prepare the hydrochloric acid solution by slowly adding reagent grade (approximately 37 %) hydrochloric acid to an equal volume of distilled water. (**Warning—**Protect eyes and use rubber gloves when handling acid. Mixing shall be done under a hood and testing shall be run under a hood.)

S7.5 The test container shall be a 1-L Erlenmeyer flask equipped with ground-glass joints and an Ahlin condenser. The volume of the solution shall be approximately 700 mL.

S7.6 Measure the thickness of the tube at five locations along the weld area and at five locations along the base-metal section. In both cases, take measurements at approximately equal longitudinal intervals along the section lengths. Make these measurements with a sharp pointed micrometer accurate to at least 0.001 in. The micrometer must be suitable for measuring the small features in the surface after testing. Typical pin micrometers have tapered anvils with a tip radius of less than 0.015 in.

S7.7 Immerse the samples into the solution. Add boiling chips and bring to a boil. Allow the chips to remain boiling throughout the test. The time of testing shall be that which is required to remove 40 to 60 % of the original base-metal thickness (usually 2 h or less). If more than 60 % of the base-metal thickness remains, the sample may be removed after 24 h.

S7.8 At the end of the test period, remove the samples from the solution, rinse with distilled water, and dry.

S7.9 After exposure to the test solution, repeat the tube-thickness measurement as in S7.6. If the thinning is not uniform across the width of the weld, then two sets of weld-metal measurement are required. One set of measurements is to be taken along the centerline of the weld. The second set of measurements is to be taken in the thinnest area of the weld.

S7.10 Calculate the corrosion ratio, R, for both sections of the weld as follows in Eq 1:

$$R = \frac{W_o - W}{B_o - B} \quad (1)$$

where:

W_o = average weld-metal thickness before the test,
W = average weld-metal thickness after the test,
B_o = average base-metal thickness before the test, and
B = average base-metal thickness after the test.

S7.11 *Acceptance Criteria*:

S7.11.1 The ratio of the thinnest section of the weld and adjacent heat affected zone versus the base metal shall be determined. The following ratios or alternatives are commonly specified:

S7.11.1.1 A corrosion ratio of 1.25 or less. If not specified by the purchase order, this is the default criteria.

S7.11.1.2 A corrosion ratio of 1.00 or less.

S7.11.1.3 Alternative ratios may be agreed between the purchaser and supplier.

S8. Special Applications

S8.1 For special applications, such as hydraulic expansion of tubes into tube sheets, there shall be no dimensional indication of the weld. Tubes ordered to this requirement shall bear the additional marking of NB.

S9. Additional Testing of Welded Tubing per ASME Request (see Note S9.1)

S9.1. When this supplement is specified in the purchase order, in certain ASME applications it is permissible to use 100 % joint efficiency for longitudinal weld, provided the following additional requirements are met:

S9.1.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E273 or E213 with the rejection criteria referenced in Specification A1016/A1016M.

S9.1.2 If Practice E273 is employed, a 100 % volumetric inspection of the entire length of each tube shall also be performed using one of the nondestructive electric tests permitted by Specification A1016/A1016M.

S9.1.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S9.1.4 In addition to the marking prescribed in Specification A1016/A1016M, “S9” shall be added after the grade designation.

NOTE S9.1—When specified, the special testing in this supplement is intended for special ASME applications. It is not mandatory for all ASME applications.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A249/A249M–16, that may impact the use of this specification. (Approved September 1, 2016)

(1) Modify S7 to include description, clarification of area to be measured, and to provide clarified alternate acceptance criteria.

Committee A01 has identified the location of selected changes to this specification since the last issue, A249/A249M–15a, that may impact the use of this specification. (Approved May 1, 2016)

(1) Moved Notes 1 and 2 into the body of Section 13.

Committee A01 has identified the location of selected changes to this specification since the last issue, A249/A249M–15, that may impact the use of this specification. (Approved December 1, 2015)

(1) Added N08020 to Table 1, Table 2, and Table 3.
(2) Modified Note A in Table 2.
(3) Added 6.3.