Designation: A 213/A 213M – 03a

Used in USDOE-NE standards

Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes[1]

This standard is issued under the fixed designation A 213/A 213M; 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 Department of Defense.

1. Scope*

1.1 This specification[2] covers minimum-wall-thickness, seamless ferritic and austenitic steel boiler, superheater, and heat-exchanger tubes, designated Grades T5, TP304, etc. These steels are listed in Tables 1 and 2.

1.2 Grades containing the letter, H, in their designation, have requirements different from those of similar grades not containing the letter, H. These different requirements provide higher creep-rupture strength than normally achievable in similar grades without these different requirements.

1.3 The tubing sizes and thicknesses usually furnished to this specification are ⅛ in. [3.2 mm] in inside diameter to 5 in. [127 mm] in outside diameter and 0.015 to 0.500 in. [0.4 to 12.7 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

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 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:*

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels[3]

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes[4]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys and Ferroalloys[4]

E 112 Test Methods for Determining Average Grain Size[5]

E 527 Practice for Numbering Metals and Alloys (UNS)[4]

2.2 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[6]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A 941.

4. Ordering Information

4.1 It shall be the responsibility of the purchaser to specify all requirements that are necessary for products under this specification. Such requirements to be considered include, but are not limited to, the following:

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

4.1.2 Name of material (seamless tubes),

4.1.3 Grade (Tables 1 and 2),

4.1.4 Condition (hot finished or cold finished),

4.1.5 Controlled structural characteristics (see 6.3),

4.1.6 Size (outside diameter and minimum wall thickness),

4.1.7 Length (specific or random),

4.1.8 Hydrostatic Test or Nondestructive Electric Test (see 10.1),

4.1.9 Specification designation and year of issue,

4.1.10 Increased sulfur (for machinability, see Note A, Table 1, and 14.3), and

4.1.11 Special requirements and any supplementary requirements selected.

5. General Requirements

5.1 Material furnished to this specification shall conform to the requirements of Specification A 450/A 450M, including any supplementary requirements that are indicated in the

[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-213 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 01.01.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

[6] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

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

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TABLE 1 Chemical Requirements for Ferritic Steel

Grade	Composition, %									Other Elements
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Chromium	Molybdenum	Titanium	Vanadium, min	
T2[A]	0.10–0.20	0.30–0.61	0.025	0.025	0.10–0.30	0.50–0.81	0.44–0.65	...	...	
T5	0.15 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65	...	...	
T5b	0.15 max	0.30–0.60	0.025	0.025	1.00–2.00	4.00–6.00	0.45–0.65	...	...	
T5c	0.12 max	0.30–0.60	0.025	0.025	0.50 max	4.00–6.00	0.45–0.65	[B]	...	
T9	0.15 max	0.30–0.60	0.025	0.025	0.25–1.00	8.00–10.00	0.90–1.10	...	...	
T11	0.05 min–0.15 max	0.30–0.60	0.025	0.025	0.50–1.00	1.00–1.50	0.44–0.65	...	...	
T12[A]	0.05 min–0.15 max	0.30–0.61	0.025	0.025	0.50 max	0.80–1.25	0.44–0.65	...	...	
T17	0.15–0.25	0.30–0.61	0.025	0.025	0.15–0.35	0.80–1.25	...	...	0.15	
T21	0.05 min–0.15 max	0.30–0.60	0.025	0.025	0.50 max	2.65–3.35	0.80–1.06	...	...	
T22	0.05 min–0.15 max	0.30–0.60	0.025	0.025	0.50 max	1.90–2.60	0.87–1.13	...	...	
T23	0.04-0.10	0.10–0.60	0.030	0.010	0.50 max	1.90-2.60	0.05-0.30	...	0.20-0.30	W 1.45-1.75 Cb 0.02-0.08 B 0.0005-0.006 N 0.030 max Al 0.030 max
T24	0.05–0.10	0.30–0.70	0.020	0.010	0.15–0.45	2.20–2.60	0.70–1.10	0.06–0.10	0.20–0.30	B 0.0015–0.0020 N 0.012 max Al 0.020 max
T91	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	8.00–9.50	0.85–1.05	...	0.18–0.25	Cb 0.06–0.1 N 0.030–0.070 Ni 0.40 max Al 0.04 max
T92	0.07–0.13	0.30–0.60	0.020	0.010	0.50 max	8.50–9.50	0.30–0.60	. . .	0.15–0.25	W 1.5–2.00 Cb 0.04–0.09 B 0.001–0.006 N 0.03–0.07 Ni 0.40 max Al 0.04 max
T122	0.07-0.14	0.70 max	0.020	0.010	0.50 max	10.00-12.50	0.25-0.60	...	0.15-0.30	W 1.50-2.50 Cu 0.30-1.70 Cb 0.04-0.10 B 0.0005-0.005 N 0.040-0.100 Ni 0.50 max Al 0.040 max
T911	0.09–0.13	0.30–0.60	0.020	0.010	0.10–0.50	8.50–10.50	0.90–1.10	...	0.18–0.25	Ni 0.40 max Cb 0.060–0.10 B 0.0003–0.006 N 0.04–0.09 Al 0.04 max W 0.90–1.10
S44400	0.025 max	1.00 max	0.040	0.030	1.00 max	17.5–19.5	1.75–2.50	[C]	...	N max 0.035 Ni + Cu max 1.00

[A] It is permissible to order T2 and T12 with 0.045 max Sulfur.
[B] Grade T5c shall have a titanium content of not less than four times the carbon content and not more than 0.70 %.
[C] S44400 shall have Ti + Cb = 0.20 + 4 (C + N) min, 0.80 max.

purchase order. Failure to comply with the general requirements of Specification A 450/A 450M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 450/A 450M, this specification shall prevail.

6. Materials and Manufacture

6.1 *Manufacture and Condition*—Tubes shall be made by the seamless process and shall be either hot finished or cold finished, as specified. Grade TP347HFG shall be cold finished.

6.2 *Heat Treatment*:

6.2.1 *Ferritic Alloy and Ferritic Stainless Steels*—The ferritic alloy and ferritic stainless steels shall be reheated for heat treatment in accordance with the requirements of Table 3. Heat treatment shall be carried out separately and in addition to heating for hot forming.

6.2.2 *Austenitic Stainless Steels*—All austenitic tubes shall be furnished in the heat-treated condition, and shall be heat treated in accordance with the requirements of Table 3. Alternatively, immediately after hot forming, while the temperature of the tubes is not less than the specified minimum solution treatment temperature, tubes may be individually quenched in water or rapidly cooled by other means.

6.3 If any controlled structural characteristics are required, these shall be so specified in the order as to be a guide as to the most suitable heat treatment.

TABLE 2 Chemical Requirements of Austenitic Steel

Grade	TP201	TP202	TP304	TP 304H	. . .	TP 304N	TP 304LN	TP 304L	TP 309Cb	TP 309H	TP 309HCb	TP 309S	. . .	TP 310Cb	TP 310H	TP 310HCb	TP 310HCbN	TP 310S		TP316	TP 316H
UNS Designation[A]	S20100	S20200	S30400	S30409	S30432	S30451	S30453	S30403	S30940	S30909	S30941	S30908	S31002	S31040	S31009	S31041	S31042	S31008	S31272	S31600	S31609
Carbon	0.15 max	0.15 max	0.08 max	0.04–0.10	0.07–0.13	0.08 max	0.035 max[B]	0.035 max[B]	0.08 max	0.04–0.10	0.04–0.10	0.08 max	0.015 max	0.08 max	0.04–0.10	0.04–0.10	0.04–0.10	0.08 max	0.08–0.12	0.08 max	0.04–0.10
Manganese, max	5.50–7.50	7.50–10.0	2.00	2.00	0.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.5–2.0	2.00	2.00
Phosphorus, max	0.060	0.060	0.040	0.040	0.045	0.040	0.040	0.040	0.045	0.045	0.045	0.045	0.020	0.045	0.040	0.045	0.030	0.045	0.030	0.040	0.040
Sulfur, max	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.015	0.030	0.030	0.030	0.030	0.030	0.015	0.030	0.030
Silicon	1.00 max	1.00 max	0.75 max	0.75 max	0.30 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.15 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.3–0.7	0.75 max	0.75 max
Nickel	3.50–5.50	4.00–6.00	8.00–11.0	8.00–11.0	7.50–10.50	8.00–11.0	8.00–11.0	8.00–13.0	12.00–16.00	12.00–15.00	12.00–16.00	12.00–15.00	19.0–22.0	19.00–22.00	19.0–22.00	19.0–22.00	17.00–23.00	19.00–22.00	14.0–16.0	11.0–14.0	11.0–14.0
Chromium	16.0–18.0	17.0–19.0	18.0–20.0	18.0–20.0	17.00–19.00	18.0–20.0	18.0–20.0	18.0–20.0	22.00–24.00	22.00–24.00	22.00–24.00	22.00–24.00	24.0–26.0	24.00–26.00	24.00–26.00	24.00–26.00	24.00–26.00	24.00–26.00	14.0–16.0	16.0–18.0	16.0–18.0
Molybdenum	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.75 max	0.75 max	0.75 max	0.75 max	0.10 max	0.75 max	. . .	0.75 max	. . .	0.75 max	1.0–1.4	2.00–3.00	2.00–3.00
Titanium		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.3–0.6	. . .	. . .
Columbium + tantalum	. . .	. . .	. . .	. . .	0.20–0.80	. . .	. . .	. . .	10× C min, 1.10 max	. . .	10 × C min, 1.10 max	. . .	. . .	10× C min, 1.10 max	. . .	10 × C min, 1.10 max	0.20–0.60	. . .	. . .	. . .	. . .
Tantalum, max	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Nitrogen[C]	0.25 max	0.25 max	. . .	. . .	0.05–0.12	0.10–0.16	0.10–0.16	. . .	. . .	. . .	. . .	. . .	0.10 max	. . .	. . .	. . .	0.15–0.35	. . .	. . .	. . .	. . .
Cerium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Others	. . .	. . .	. . .	. . .	B 0.001–0.010 Al 0.003–0.030 Cu 2.5–3.5	. . .	. . .	. . .		. . .			. . .		. . .		. . .		B 0.004–0.008	. . .	

TABLE 2 *Continued*

Grade	TP316L	TP316N	TP 316LN	TP317	TP317L	TP321	TP 321H	TP347	TP 347H	TP 347LN	TP 347HFG	TP348	TP 348H
UNS Designation[A]	S31603	S31651	S31653	S31700	S31703	S32100	S32109	S34700	S34709	S34751		S34800	S34809
Carbon	0.035 max[B]	0.08 max	0.035 max[B]	0.08 max	0.035 max	0.08 max	0.04–0.10	0.08 max	0.04–0.10	0.005–0.020	0.06–0.10	0.08 max	0.04–0.10
Manganese, max	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Phosphorus, max	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Sulfur, max	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Silicon	0.75 max[C]	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max	0.75 max
Nickel	10.0–15.0	11.0–14.0	11.0–14.0	11.0–14.0	11.0–15.0	9.00–13.0	9.00–13.0	9.00–13.0	9.00–13.0	9.0–13.0	9.00–13.0	9.00–13.0	9.00–13.0
Chromium	16.0–18.0	16.0–18.0	16.0–18.0	18.0–20.0	18.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0
Molybdenum	2.00–3.00	2.00–3.00	2.00–3.00	3.00–4.00	3.00–4.00	. . .	. . .	. . .	. . .	. . .		. . .	. . .
Titanium	. . .	. . .	. . .	. . .	. . .	[D]	[E]	. . .	. . .	. . .	. . .	. . .	. . .
Columbium + tantalum	. . .	. . .	. . .	. . .	. . .	. . .	. . .	[F]	[G]	0.2–0.5[H]	8×c–1.0	[F]	[G]
Tantalum, max	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .		0.10	0.10
Nitrogen[I]	. . .	0.10–0.16	0.10–0.16	. . .	. . .	. . .	. . .	. . .	. . .	0.06–0.10		. . .	. . .
Cerium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .		. . .	. . .
Others	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .		. . .	. . .

TABLE 2 *Continued*

Grade	XM-15								. . .	XM-19	. . .	. . .	. . .	. . .
UNS Designation[A]	S38100	S30615	S30815	S31050	S21500	S31725	S31726	S32615	S33228	S20910	S25700	S32050	S34565	S31254
Carbon	0.08 max	0.016–0.24	0.05–0.10	0.025	0.06–0.15	0.03 max	0.03 max	0.07 max	0.04–0.08	0.06 max	0.02 max	0.030 max	0.030 max	0.020 max
Manganese, max	2.00	2.00	0.80	2.00	5.50–7.0	2.00	2.00	2.00	1.0	4.00–6.00	2.0	1.50	5.0–7.0	1.00
Phosphorus, max	0.030	0.030	0.040	0.020	0.040	0.040	0.040	0.045	0.020	0.04	0.025	0.035	0.030	0.030
Sulfur, max	0.030	0.030	0.030	0.015	0.030	0.030	0.030	0.030	0.015	0.03	0.010	0.020	0.010	0.010
Silicon	1.50–2.50	3.2-4.0	1.40–2.00	0.4	0.2–1.0	0.75	0.75	4.8-6.0	0.30	1.00 max	6.5–8.0	1.00 max	1.00 max	0.80 max
Nickel	17.5–18.5	13.5–16.0	10.0–12.0	20.5–23.5	9.00–11.0	13.5–17.5	13.5–17.5	19.0–22.0	31.0–33.0	11.5–13.5	22.0–25.0	20.0–22.0	16.0–18.0	17.5–18.5
Chromium	17.0–19.0	17.0–19.5	20.0–22.0	24.0–26.0	14.0–16.0	18.0–20.0	17.0–20.0	16.5–19.5	26.0–28.0	20.5–23.5	8.0–11.0	22.0–24.0	23.0–25.0	19.5–20.5
Molybdenum	. . .	. . .	. . .	1.6–2.6	0.8–1.20	4.0–5.00	4.0–5.00	0.3–1.5	. . .	1.50–3.00	0.50 max	6.0–6.8	4.0–5.0	6.0–6.5
Titanium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Columbium + tantalum	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.6–1.0	0.10–0.30	. . .	. . .	. . .	. . .
Tantalum, max	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Nitrogen[I]	. . .	. . .	0.14–0.20	0.09–0.15	. . .	0.10 max	0.10–0.20	. . .	. . .	0.20–0.40	. . .	0.21–0.32	0.40–0.60	0.18–0.22
Cerium	. . .	. . .	0.03–0.08	. . .	. . .	. . .	. . .	. . .	0.05–0.10	. . .	. . .	. . .	. . .	. . .
Others	. . .	Al 0.8–1.5	. . .		Cb 0.75–1.25 V 0.15–0.40 B 0.003–0.009	Cu 0.75 max	Cu 0.75 max	Cu 1.5–2.5	Al 0.025 max	V 0.10–0.30	. . .	Cu 0.40 max	Cb 0.10 max	Cu 0.50–1.00

[A] New designation established in accordance with Practice E 527 and SAE J1086.
[B] For small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes are those less than 0.049 in. [1.2 mm] in average wall thickness (0.044 in. [1.1 mm] in minimum wall thickness).
[C] For seamless TP316L tubes, the silicon maximum shall be 1.00 %.
[D] Grade TP321 shall have a titanium content of not less than five times the carbon content and not more than 0.60 %.
[E] Grade TP321H shall have a titanium content of not less than four times the carbon content and not more than 0.60 %.
[F] Grades TP347 and TP348 shall have a columbium plus tantalum content of not less than ten times the carbon content and not more than 1.00 %.
[G] Grades TP347H and TP348H shall have a columbium plus tantalum content of not less than eight times the carbon content and not more than 1.0 %.
[H] Grade TP347LN shall have a columbium (niobium) plus tantalum content of not less than 15 times the carbon content.
[I] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

7. Chemical Composition

7.1 *Composition Requirements*:

7.1.1 The alloy steels shall conform to the chemical requirements prescribed in Table 1.

7.1.2 The stainless steels shall conform to the chemical requirements prescribed in Table 2.

7.2 *Product Analysis*:

7.2.1 An analysis of either one billet or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

7.2.2 If the original test for product analysis fails, retests of two additional billets 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 (as described in Section 13) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes that do not meet the requirements of the specification shall be rejected.

8. Grain Size

8.1 Grain size shall be as prescribed in Table 3, as determined in accordance with Test Methods E 112.

8.2 Grain size determinations, to demonstrate compliance with 8.1, shall be made on one end of one finished tube from each lot. See 13.1.

9. Mechanical Properties

9.1 *Tensile Requirements*:

9.1.1 The material shall conform to the requirements as to tensile properties prescribed in Table 4.

9.1.2 Table 5 gives the computed minimum elongation values for each 1⁄32-in. [0.8-mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equations. For Grades T23, T24, T91, T92, T122, T911, and S44400: $E = 32t + 10.00$ [$E = 1.25t + 10.00$]. For all other ferritic alloy grades: $E = 48t + 15.00$ [$E = 1.87t + 15.00$].

where:

E = elongation in 2 in. or 50 mm, %, and
t = actual thickness of specimen, in. [mm].

9.1.3 One tension test shall be made on a specimen from one tube 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 13.2.

9.2 *Hardness Requirements*:

9.2.1 The material shall conform to the hardness requirements prescribed in Table 4. See 13.2.

9.2.2 Brinell, Vickers, or Rockwell hardness tests shall be made on specimens from two tubes from each lot. See 13.2.

9.3 *Flattening Test*—One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring test, from each lot. See 13.1.

9.4 *Flaring Test*—One flaring 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 13.1.

9.5 Mechanical property requirements do not apply to tubing thinner than 1⁄8 in. [3.2 mm].

10. Hydrostatic or Nondestructive Electric Test

10.1 Each tube shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

11. Forming Operations

11.1 Tubes, when inserted in a boiler or tube sheet, shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects. See Note 1.

NOTE 1—Certain of the ferritic steels covered by this specification will harden if cooled rapidly from above their critical temperature. Some will air harden, that is, become hardened to an undesirable degree when cooled in air from high temperatures, particularly chromium-containing steels with chromium of 4 % and higher. Therefore, operations that involve heating such steels above their critical temperatures, such as welding, flanging, and hot bending, should be followed by suitable heat treatment.

12. Surface Condition

12.1 Ferritic alloy cold-finished steel tubes shall be free of scale and suitable for inspection. A slight amount of oxidation is not considered scale.

12.2 Ferritic alloy hot-finished steel tubes shall be free of loose scale and suitable for inspection.

12.3 Stainless steel tubes shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

12.4 Any special finish requirement shall be subject to agreement between the supplier and the purchaser.

13. Sampling

13.1 For flattening, flaring, and grain size requirements, he term lot applies to all tubes, prior to cutting, of the same size (see 4.1.6) that 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 from the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace or when the heat-treated condition is obtained directly by quenching after hot forming, 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 6.

13.2 For tensile and hardness test requirements, the term lot applies to all tubes prior to cutting, of the same size (see 4.1.6) that 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 that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, or when the heat-treated condition is obtained directly by quenching after hot forming, 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; or all tubes of the same size and heat, hot formed and quenched in the same production run, except as prescribed in 9.1.3.

TABLE 3 Heat Treatment and Grain Size Requirements[A]

Grade	UNS Number	Heat Treat Type	Austenitizing/ Solutioning Temperature, min or range	Cooling Media	Subcritical Annealing or Tempering Temperature, min or range °F [°C]	ASTM Grain Size No.[B]
			Ferritic Alloy Steels			
T2	K11547	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	…	…
		subcritical anneal	…	…	1200 to 1350°F [650 to 730°C]	…
T5	K41545	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250°F [675°C]	…
T5b	K51545	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250°F [675°C]	…
T5c	K41245	subcritical anneal	…	air or furnace	1350°F [730°C][C]	…
T9	S50400	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250°F [675°C]	…
T11	K11597	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1200°F [650°C]	…
T12	K11562	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	…	…
		subcritical anneal	…	…	1200 to 1350°F [650 to 730°C]	…
T17	K12047	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1200°F [650°C]	…
T21	K31545	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250°F [675°C]	…
T22	K21590	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250°F [675°C]	…
T23	K40712	normalize and temper	1900°F [1040°C]	…	1350°F [730°C]	…
T24		normalize and temper	1800°F [980°C]	…	1350°F [730°C]	…
T91	K90901	normalize and temper	1900°F [1040°C]	…	1350°F [730°C]	…
T92	K92460	normalize and temper	1900°F [1040°C]	…	1350°F [730°C]	…
T122	K91261	normalize and temper	1900°F [1040°C]	…	1350°F [730°C]	…
T911		normalize and temper	1900 to 1975°F [1040 to 1080°C]	[D]	1365 to 1435°F [740 to 780°C]	…
			Austenitic Stainless Steels			
TP201	S20100	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP202	S20200	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
XM-19	S20910	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
…	S21500	solution treatment	1900°F [1040°C][E]	water or other rapid cool	…	…
…	S25700	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
…	S30150:	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP304	S30400	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP304L	S30403	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP304H	S30409	solution treatment	1900°F [1040°C]	water or other rapid cool	…	7
…	S30432	solution treatment	2000°F [1100°C]	water or other rapid cool	…	…
TP304N	S30451	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP304LN	S30453	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
…	S30615	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
…	S30815	solution treatment	1920°F [1050°C]	water or other rapid cool	…	…
TP309S	S30908	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP309H	S30909	solution treatment	1900°F [1040°C]	water or other rapid cool	…	7
TP309Cb	S30940	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP309HCb	S30941	solution treatment	1900°F [1040°C][F]	water or other rapid cool	…	7
…	S31002	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP310S	S31008	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP310H	S31009	solution treatment	1900°F [1040°C]	water or other rapid cool	…	7
TP310Cb	S31040	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP310HCb	S31041	solution treatment	1900°F [1040°C][F]	water or other rapid cool	…	7
TP310HCbN	S31042	solution treatment	1900°F [1040°C][F]	water or other rapid cool	…	7
…	S31254	solution treatment	2100°F [1150°C]	water or other rapid cool	…	…
…	S31272	solution treatment	1920°F [1050°C]	water or other rapid cool	…	…
TP316	S31600	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP316L	S31603	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP316H	S31609	solution treatment	1900°F [1040°C]	water or other rapid cool	…	7
TP316N	S31651	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP316LN	S31653	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP317	S31700	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP317L	S31703	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
…	S31725	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
…	S32050	solution treatment	2100°F [1150°C]	water or other rapid cool	…	…
TP321	S32100	solution treatment	1900°F [1040°C][F]	water or other rapid cool	…	…

TABLE 3 *Continued*

Grade	UNS Number	Heat Treat Type	Austenitizing/ Solutioning Temperature, min or range	Cooling Media	Subcritical Annealing or Tempering Temperature, min or range °F [°C]	ASTM Grain Size No.[B]
TP321H	S32109	solution treatment	cold worked: 2000°F [1090°C] hot rolled: 1925°F [1050°C][F]	water or other rapid cool	…	7
…	S32615	solution treatment	1900°F [1040°C]	water or other rapid cool	…	3 or finer
…	S32716	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
…	S33228	solution treatment	2050°F [1120°C]	water or other rapid cool	…	…
. . .	S34565	solution treatment	2050°F [1120°C] 2140°F [1170°C]	water or other rapid cool	…	…
TP347	S34700	solution treatment	1900°F [1040°C][F]	water or other rapid cool	…	…
TP347H	S34709	solution treatment	cold worked: 2000°F [1100°C] hot rolled: 1925°F [1050°C][F]	water or other rapid cool	…	7
TP347HFG	S34710	solution treatment,[G]	2150°F [1175°C]	water or other rapid cool	…	7-10
TP347LN	S34751	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
TP348	S34800	solution treatment	1900°F [1040°C][F]	water or other rapid cool	…	…
TP348H	S34809	solution treatment	cold worked: 2000°F [1100°C] hot rolled: 1925°F [1050°C][F]	water or other rapid cool	…	7
…	S35045	solution treatment	2000°F [1100°C]	still air cool or faster	…	…
XM-15	S38100	solution treatment	1900°F [1040°C]	water or other rapid cool	…	…
			Ferritic Steels			
T2	K11547	full or isothermal anneal	…	…	…	…
		subcritical anneal[B]	…	…	1200 to 1350°F [650 to 730°C]	…
		normalize and temper	…	…	…	…
T5	K41545	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250°F [675°C]	…
T5b	K51545	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250°F [675°C]	…
T5c	K41545?	subcritical anneal	…	air or furnace	1350°F [730°C], approximately	…
T9	S50400	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250°F [675°C]	…
T11	K11597	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1200°F [650°C]	…
T12	K11562	full or isothermal anneal	…	…	…	…
		subcritical anneal[B]	…	…	1200 to 1350°F [650 to 730°C]	…
		normalize and temper	…	…	…	…
T17	K12047	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1200°F [650°C]	…
T21	K31545	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250°F [675°C]	…
T22	K21590	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250°F [675°C]	…
T23		normalized and tempered	1900°F [1040°C]	…	1350°F [730°C]	…
T91	K90901	normalized and tempered	1900°F [1040°C]	…	1350°F [730°C]	…
T92	K92460	normalized and tempered	1900°F [1040°C]	…	1350°F [730°C]	…
T122		normalized and tempered	1900°F [1040°C]	…	1350°F [730°C]	…
			Ferritic Stainless Steels			
	S44400	subcritical anneal	1800°F [980°C]	…	1400°F [760°C]	…
	S44400	subcritical anneal	…	…	1400°F [760°C]	…

[A] Where ellipses (…) appear in this table there is no requirement.
[B] ASTM Grain Size No. listed, or coarser, unless otherwise indicated.
[C] Approximately, to achieve properties.
[D] Accelerated cooling from the normalizing temperature shall be permitted for section thicknesses greater than 3 in. [75 mm].
[E] A maximum solution treating temperature of 2100°F [1150°C] is recommended for UNS S21500.
[F] 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 resolution anneal shall be used subsequent to the higher-temperature solution anneal prescribed in this table.
[G] Solution treatment shall be preceded by a softening heat treatment prior to cold-working. The softening temperature shall be at least 90°F [50°C] higher than the solution heat treatment temperature, which shall be at 2150°F [1180°C] minimum.

TABLE 4 Tensile and Hardness Requirements

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %[A,B]	Hardness, Max	
					Brinell/Vickers	Rockwell
Ferritic Grades:						
T5b	...	60[415]	30[205]	30	179 HB/190HV	89 HRB
T7	...	60[415]	30[205]	30	179 HB/190HV	89 HRB
T9	...	60[415]	30[205]	30	179 HB/190HV	89 HRB
T12	...	60[415]	32[220]	30	163 HB/170 HV	85 HRB
T23	...	74[510]	58[400]	20	220 HB/230 HV	97 HRB
T24	...	85[585]	60[415]	20	250 HB/265 HV	25 HRC
T91	...	85[585]	60[415]	20	250 HB/265 HV	25 HRC
T92	K92460	90[620]	64[440]	20	250 HB/265 HV	25 HRC
T122	...	90[620]	58[400]	20	250 HB/265 HV	25 HRC
T911	K91061	90[620]	64[440]	20	250 HB/265 HV	25 HRC
S44400	...	60[415]	40[275]	20	217 HB/230 HV	96 HRB
All other grades		60[415]	30[205]	30	163 HB/170 HV	85 HRB
Austenitic Grades:						
TP201	S20100	95[655]	38[260]	35	219 HB/230 HV	95 HRB
TP202	S20200	90[620]	45[310]	35	219 HB/230 HV	95 HRB
TP304	S30400	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP304H	S30409	75[515]	30[205]	35	192 HB/200 HV	90 HRB
...	S30432	80[550]	30[205]	35	192 HB/200 HV	90 HRB
TP304N	S30451	80[550]	35[240]	35	192 HB/200 HV	90 HRB
TP304L	S30403	70[485]	25[170]	35	192 HB/200 HV	90 HRB
TP304LN	S30453	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP309Cb	S30940	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP309H	S30909	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP309HCb	S30941	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP309S	S30908	75[515]	30[205]	35	192 HB/200 HV	90 HRB
...	S31002	73[500]	30[205]	35	192 HB/200 HV	90 HRB
TP310Cb	S31040	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP310H	S31009	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP310HCb	S31041	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP310HCbN	S31042	95[655]	43[295]	30	256 HB	100 HRB
TP310S	S31008	75[515]	30[205]	35	192 HB/200 HV	90 HRB
	S31272	65[450]	29[200]	35	217 HB	95 HRB
	S31254					
t ≤0.187 in. [5.00 mm]	...	98 [675]	45 [310]	35	220 HB/230 HV	96 HRB
t >0.187 in. [5.00 mm]	...	95 [655]	45 [310]	35	220 HB/230 HV	96 HRB
TP316	S31600	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP316H	S31609	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP316L	S31603	70[485]	25[170]	35	192 HB/200 HV	90 HRB
TP316N	S31651	80[550]	35[240]	35	192 HB/200 HV	90 HRB
TP316LN	S31653	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP317	S31700	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP317L	S31703	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP321	S32100	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP321H	S32109	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP347	S34700	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP347H	S34709	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP347LN	S34751	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP347HFG	...	80[550]	30[205]	35	192 HB/200 HV	90 HRB
TP348	S34800	75[515]	30[205]	35	192 HB/200 HV	90 HRB
TP348H	S34809	75[515]	30[205]	35	192 HB/200 HV	90 HRB
XM-15	S38100	75[515]	30[205]	35	192 HB/200 HV	90 HRB
...	S30615	90[620]	40[275]	35	192 HB/200 HV	90 HRB
...	S30815	87[600]	45[310]	40	217 HB	95 HRB
...	S31050:					
t ≤ 0.25 in.		84[580]	39[270]	25	217 HB	95 HRB
t > 0.25 in.		78[540]	37[255]	25	217 HB	95 HRB
...	S33228	73[500]	27[185]	30	192 HB/200 HV	90 HRB
...	S21500	78[540]	33[230]	35	192 HB/200 HV	90 HRB
...	S31725	75[515]	30[205]	35	192 HB/200 HV	90 HRB
...	S32716	80[550]	35[240]	35	192 HB/200 HV	90 HRB
...	S32615	80[550]	32[220]	25	192 HB/200 HV	90 HRB

TABLE 4 *Continued*

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %[A,B]	Hardness, Max	
					Brinell/Vickers	Rockwell
XM-19	S20910	100[690]	55[380]	35	250 HB/265 HV	25 HRC
...	S25700	78[540]	35[240]	50	217 HB	95 HRB
...	S32050	98[675]	48[330]	40	256 HB	100 HRB
...	S34565	115[790]	60[415]	35	241 HB	100 HRB

[A] When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimens with gage length equal to 4*D* (4 times the diameter) is used, the minimum elongation shall be 22 % for all ferritic grades except S44400, T23 T24, T91, T92, and T911.

[B] For longitudinal strip tests a deduction from the basic minimum elongation values of 1.00 % for S44400, T23, T24, T91, T92, and T122, T911, 1.50 % for all other ferritic grades for each 1/32-in. [0.8-mm] decrease in wall thickness below 5/16 in. [8 mm] shall be made.

TABLE 5 Computed Minimum Values[A]

Wall Thickness		Elongation in 2 in. or 50 mm, min, %	
in.	mm	S44400, T23, T24 T91, T92, T122, and T911	All Other Ferritic Grades
5/16 [0.312]	8	20	30
9/32 [0.281]	7.2	19	29
1/4 [0.250]	6.4	18	27
7/32 [0.219]	5.6	17	26
3/16 [0.188]	4.8	16	24
5/32 [0.156]	4	15	23
1/8 [0.125]	3.2	14	21
3/32 [0.094]	2.4	13	20
1/16 [0.062]	1.6	12	18
0.062 to 0.035, excl	1.6 to 0.9	12	17
0.035 to 0.022, excl	0.9 to 0.6	11	17
0.022 to 0.015 incl	0.6 to 0.4	11	16

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

TABLE 6 Number of Tubes in a Lot Heat Treated by the Continuous Process or by Direct Quench After Hot Forming

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

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall include the condition: hot finished or cold finished.

14.2 For the austenitic stainless steels having a grain size requirement (see Table 2) the marking shall also include the heat number and heat-treatment lot identification.

14.3 When either T2 or T12 are ordered with higher sulfur contents as permitted by Note B of Table 1, the marking shall include the letter, S, following the grade designation: T2S or T12S.

15. Keywords

15.1 alloy steel tubes; austenitic stainless steel; boiler tubes; ferritic stainless steel; heat exchanger tubes; high-temperature applications; seamless steel tubes; steel tubes; superheater tubes; temperature service applications-high

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.

S1.2 When stress-relieved tubes are specified, tubes shall be given a heat treatment at 1500 to 1650°F [815 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 supplier.

S2. Stabilizing Heat Treatment

S2.1 Subsequent to the solution anneal required in Section 6, Grades TP309HCb, TP310HCb, TP310HCbN, 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.

S3. Unstraightened Tubes

S3.1 When the purchaser specifies tubes unstraightened after final heat treatment (such as coils), the minimum yield strength of Table 3 shall be reduced by 5 ksi [35 MPa].

S3.2 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.).

S4. Intergranular Corrosion Test

S4.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S4.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S4.2 A stabilization heat treatment in accordance with Supplementary Requirement S2 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 213/A 213M – 03) that may impact the use of this standard (Approved April 10, 2003).

(1) Added UNS S31254 to Table 4 and Table 2.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 213/A 213M – 01a) that may impact the use of this standard. (Approved Feb. 10, 2003.)

(1) Revised stainless steel chemistry table to conform to Guide A 959.
(2) Referenced Terminology A 941 for definitions and removed definitions redundant with Terminology A 941.
(3) Clarified meaning of ellipses in tables.
(4) Moved lot definitions into the text.
(5) Deleted requirements that are in Specification A 450/A 450M.
(6) Revised organization to conform to Guide A 994.
(7) Tabularized heat treatment requirements.
(8) Tabularized grain-size requirements of stainless steels.
(9) Added UNS numbers.
(10) Corrected the name of Grade 18Cr-2Mo to Grade 444, UNS S44400, and changed its location to the table for stainless steels.
(11) Clarified the requirement to reheat all of the ferritic alloy and ferritic stainless steels before heat treatment.
(12) Integrated the product analysis of Grade 91 with the heat anlysis.
(13) Clarified that the tension test specimen is from one tube for lots of 50 tubes or less.
(14) Deleted paragraph 11.5, which was in conflict with Section 12.
(15) Considered higher chromium content steels than 9 % Cr in old Note 4, which is now new Note 1.
(16) Added Vickers hardness tests to 11.4.

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