

SPECIFICATION FOR SEAMLESS FERRITIC AND AUSTENITIC ALLOY-STEEL BOILER, SUPERHEATER, AND HEAT-EXCHANGER TUBES



SA-213/SA-213M

(Identical with ASTM Specification A 213/A 213M-08 except for the additional H grade heat treatment requirements in 6.2.)

1. Scope

1.1 This specification covers 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 $\frac{1}{8}$ 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 or, if specified in the order, average wall thickness. Tubing having other diameters 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

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

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 112 Test Methods for Determining Average Grain Size

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, unless average wall thickness is specified),

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 B, Table 1, and 15.3), and

4.1.11 Special requirements and any supplementary requirements selected.

5. General Requirements

5.1 Product furnished to this specification shall conform to the requirements of Specification A 1016/A 1016M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 1016/A 1016M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 1016/A 1016M, 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. Other than for Grades S30432, S30815, S30942, S31035, S31272, S33228, and H Grades, seamless tubing immediately following hot forming may be individually quenched in water or rapidly cooled by other means, provided that the temperature of the tubes after hot forming is not less than the minimum specified solution temperature (direct quenched). For H grades, as well as Grades S30432, S30815, S30942, S31035, S31272, and S33228, the tubes shall be reheated to the specified solution treatment temperature for the required time before quenching.

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.

7. Chemical Composition

7.1 Composition Requirements:

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

7.1.2 The stainless steels shall conform to the chemical requirements given 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 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 given 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 14.1.

9. Mechanical Properties

9.1 Tensile Requirements:

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

9.1.2 Table 5 gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown in Table 5, 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 Grade T36: $E = 32t + 5.0$ [$E = 1.25t + 5.0$]. For all other ferritic alloy grades: $E = 48t + 15.00$ [$E = 1.87t + 15.00$].

where:

E = elongation in 2 in. [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 14.2.

9.2 Hardness Requirements:

9.2.1 The material shall conform to the hardness requirements given in Table 4. See 14.2.

9.2.2 Brinell, Vickers, or Rockwell hardness tests shall be made on specimens from two tubes from each lot. See 14.2.

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 14.1.

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 14.1.

9.5 Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in inside diameter or thinner than 0.015 in. [0.4 mm] in thickness.

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. Permissible Variations from the Specified Wall Thickness

12.1 Permissible variations from the specified minimum wall thickness shall be in accordance with Specification A 1016/A 1016M.

12.2 Permissible variations from the specified average wall thickness are $\pm 10\%$ of the specified average wall thickness.

13. Surface Condition

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

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

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

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

14. Sampling

14.1 For flattening, flaring, and grain size 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 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.

14.2 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.

15. Product Marking

15.1 In addition to the marking prescribed in Specification A 1016/A 1016M, the marking shall include: the condition, hot finished or cold finished; and the wall designation, minimum wall or average wall.

15.2 For the austenitic stainless steels having a grain size requirement (see Table 3) the marking shall also include the heat number and heat-treatment lot identification.

15.3 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.

16. Keywords

16.1 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

TABLE 1 CHEMICAL COMPOSITION LIMITS, %^A, FOR LOW ALLOY STEEL

Grade	UNS Designation	Composition, %													
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Vanadium	Boron	Niobium	Nitrogen	Aluminum	Tungsten	Other Elements
T2	K11547	0.10-0.20	0.30-0.61	0.025	0.025 ^B	0.10-0.30	...	0.50-0.81	0.44-0.65	...	...	...	...	...	...
T5	K41545	0.15	0.30-0.60	0.025	0.025	0.50	...	4.00-6.00	0.45-0.65	...	...	...	...	...	...
T5b	K51545	0.15	0.30-0.60	0.025	0.025	1.00-2.00	...	4.00-6.00	0.45-0.65	...	...	...	...	...	...
T5c	K41245	0.12	0.30-0.60	0.025	0.025	0.50	...	4.00-6.00	0.45-0.65	...	...	...	...	...	Ti 4xC-0.70
T9	K90941	0.15	0.30-0.60	0.025	0.025	0.25-1.00	...	8.00-10.00	0.90-1.10	...	...	...	...	...	...
T11	K11597	0.05-0.15	0.30-0.60	0.025	0.025	0.50-1.00	...	1.00-1.50	0.44-0.65	...	...	...	...	...	...
T12	K11562	0.05-0.15	0.30-0.61	0.025	0.025 ^B	0.50	...	0.80-1.25	0.44-0.65	...	...	...	...	...	...
T17	K12047	0.15-0.25	0.30-0.61	0.025	0.025	0.15-0.35	...	0.80-1.25	...	0.15	...	...	...	...	...
T21	K31545	0.05-0.15	0.30-0.60	0.025	0.025	0.50-1.00	...	2.65-3.35	0.80-1.06	...	...	...	...	...	...
T22	K21590	0.05-0.15	0.30-0.60	0.025	0.025	0.50	...	1.90-2.60	0.87-1.13	...	...	...	...	...	...
T23	K40712	0.04-0.10	0.10-0.60	0.030	0.010	0.50	...	1.90-2.60	0.05-0.30	0.20-0.30	0.0005-0.006	0.02-0.08	0.03	0.030	1.45-1.75
T24	K30736	0.05-0.10	0.30-0.70	0.020	0.010	0.15-0.45	...	2.20-2.60	0.90-1.10	0.20-0.30	0.0015-0.007	...	0.012	0.02	...
T36	K21001	0.10-0.17	0.80-1.20	0.030	0.025	0.25-0.50	1.00-1.30	0.30	0.25-0.50	0.02	...	0.015-0.045	0.02	0.050	...
T91	K90901	0.07-0.14	0.30-0.60	0.020	0.010	0.20-0.50	0.40	8.0-9.5	0.85-1.05	0.18-0.25	...	0.06-0.10	0.030-0.070	0.02	...
T92	K92460	0.07-0.13	0.30-0.60	0.020	0.010	0.50	0.40	8.5-9.5	0.30-0.60	0.15-0.25	0.001-0.006	0.04-0.09	0.030-0.070	0.02	1.5-2.00
T122	K91271	0.07-0.14	0.70	0.020	0.010	0.50	0.50	10.0-11.5	0.25-0.60	0.15-0.30	0.0005-0.005	0.04-0.10	0.040-0.100	0.02	1.50-2.50
T911	K91061	0.09-0.13	0.30-0.60	0.020	0.010	0.10-0.50	0.40	8.5-9.5	0.90-1.10	0.18-0.25	0.0003-0.006	0.06-0.10	0.040-0.090	0.02	0.90-1.10

^A Maximum, unless range or minimum is indicated. Where ellipses (...) appear in this table, there is no requirement, and analysis for the element need not be determined or reported.

^B It is permissible to order T2 and T12 with a sulfur content of 0.045 max. See 15.3.

TABLE 2 CHEMICAL COMPOSITION LIMITS, %^A, FOR AUSTENITIC AND FERRITIC STAINLESS STEEL

Grade	UNS Designation	Composition											
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen ^B	Niobium	Titanium	Other Elements
TP201	S20100	0.15	5.5-7.5	0.060	0.030	1.00	16.0-18.0	3.5-5.5	...	0.25	...	...	...
TP202	S20200	0.15	7.5-10.0	0.060	0.030	1.00	17.0-19.0	4.0-6.0	...	0.25	...	...	...
XM-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	0.10-0.30	...	V 0.10-0.30
^C	S21500	0.06-0.15	5.5-7.0	0.045	0.030	0.20-1.00	14.0-16.0	9.0-11.0	0.80-1.20	...	0.75-1.25	...	B 0.003-0.009, V 0.15-0.40
^C	S25700	0.02	2.00	0.025	0.010	6.5-8.0	8.0-11.5	22.0-25.0	0.50	...	...	...	...
TP304	S30400	0.08	2.00	0.045	0.030	1.00	18.0-20.0	8.0-11.0	...	...	...	...	...
TP304L	S30403	0.035 ^D	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	...	...	...	...	...
^C	S30432	0.07-0.13	1.00	0.040	0.010	0.30	17.0-19.0	7.5-10.5	...	0.05-0.12	0.30-0.60	...	Al 0.003-0.030, B 0.001-0.010, Cu 2.5-3.5
^C	S30434	0.07-0.14	2.00	0.040	0.010	1.00	17.5-19.5	9.0-12.0	...	...	0.10-0.40 ^F	0.10-0.25 ^F	B 0.001-0.004 Cu 2.50-3.50
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	S30453	0.035 ^D	2.00	0.045	0.030	1.00	18.0-20.0	8.0-11.0	...	0.10-0.16	...	...	...
^C	S30615	0.016-0.24	2.00	0.030	0.030	3.2-4.0	17.0-19.5	13.5-16.0	...	...	...	...	Al 0.8-1.5
^C	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	...	...	...	...	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00	22.0-24.0	12.0-16.0	...	...	10xC-1.10	...	...
TP309HCb	S30941	0.04-0.10	2.00	0.045	0.030	1.00	22.0-24.0	12.0-16.0	...	...	10xC-1.10	...	...
...	S30942	0.03-0.10	2.00	0.040	0.030	1.00	21.0-23.0	14.5-16.5	...	0.10-0.20	0.50-0.80	...	B-0.001-0.005
^C	S31002	0.02	2.00	0.020	0.015	0.15	24.0-26.0	19.0-22.0	0.10	0.10	...	...	...
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	...	...	...	...	...
...	S31035	0.04-0.10	0.60	0.030	0.015	0.40	21.5-23.5	23.5-26.5	...	0.15-0.30	0.30-0.60	...	W 2.0-4.0 Co 1.0-2.0 Cu 2.0-3.5 B 0.002-0.008
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00	24.0-26.0	19.0-22.0	...	...	10xC-1.10	...	...
TP310HCb	S31041	0.04-0.10	2.00	0.045	0.030	1.00	24.0-26.0	19.0-22.0	...	...	10xC-1.10	...	...
TP310HCbN	S31042	0.04-0.10	2.00	0.045	0.030	1.00	24.0-26.0	19.0-22.0	...	0.15-0.35	0.20-0.60	...	...
TP310MoLN	S31050	0.025	2.00	0.020	0.030	0.40	24.0-26.0	21.0-23.0	2.00-3.00	0.10-0.16	...	...	...
^C	S31060	0.05-0.10	1.00	0.040	0.030	0.50	22.0-24.0	10.0-12.5	...	0.18-0.25	...	...	Ce + La 0.025-0.070 B 0.001-0.010 Cu 0.50-1.00
^C	S31254	0.020	1.00	0.030	0.010	0.80	19.5-20.5	17.5-18.5	6.0-6.5	0.18-0.22	...	...	...
^C	S31272	0.08-0.12	1.50-2.00	0.030	0.015	0.30-0.70	14.0-16.0	14.0-16.0	1.00-1.40	...	...	0.30-0.60	B 0.004-0.008 Cu 0.50-1.50
^C	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	...	...	...
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	S31603	0.035 ^D	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	11.0-14.0	2.00-3.00	...	...	...	...
TP316Ti	S31635	0.08	2.00	0.045	0.030	0.75	16.0-18.0	10.0-14.0	2.00-3.00	0.10	...	5X (C + N)-0.70	...
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	S31653	0.035 ^D	2.00	0.045	0.030	1.00	16.0-18.0	10.0-13.0	2.00-3.00	0.10-0.16	...	...	...
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	0.035	2.00	0.045	0.030	1.00	18.0-20.0	11.0-15.0	3.0-4.0	...	...	...	...

TABLE 2 CHEMICAL COMPOSITION LIMITS, %^A, FOR AUSTENITIC AND FERRITIC STAINLESS STEEL (CONT'D)

Grade	UNS Designation	Composition											
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen ^B	Niobium	Titanium	Other Elements
TP317LM	S31725	0.03	2.00	0.045	0.030	1.00	18.0-20.0	13.5-17.5	4.0-5.0	0.20	...	...	Cu 0.75
TP317LMN	S31726	0.03	2.00	0.045	0.030	1.00	17.0-20.0	13.5-17.5	4.0-5.0	0.10-0.20	...	...	Cu 0.75
^C	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	...	...	Cu 0.40
TP321	S32100	0.08	2.00	0.045	0.030	1.00	17.0-19.0	9.0-12.0	...	...	...	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	...	...	...	4(C + N)-0.70	...
^C	S32615	0.07	2.00	0.045	0.030	4.8-6.0	16.5-19.5	19.0-22.0	0.30-1.50	...	...	...	Cu 1.50-2.50
^C	S33228	0.04-0.08	1.00	0.020	0.015	0.30	26.0-28.0	31.0-33.0	...	...	0.60-1.00	...	Ce 0.05-0.10, Al 0.025
^C	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	0.10	...	...
TP347	S34700	0.08	2.00	0.045	0.030	1.00	17.0-20.0	9.0-13.0	...	...	10xC-1.10	...	...
TP347H	S34709	0.04-0.10	2.00	0.045	0.030	1.00	17.0-19.0	9.0-13.0	...	...	8xC-1.10	...	...
TP347HFG	S34710	0.06-0.10	2.00	0.045	0.030	1.00	17.0-19.0	9.0-13.0	...	...	8xC-1.10	...	...
TP347LN	S34751	0.005-0.020	2.00	0.045	0.030	1.00	17.0-19.0	9.0-12.0	...	0.06-0.10	0.20-0.50 ^F	...	...
TP348	S34800	0.08	2.00	0.045	0.030	1.00	17.0-19.0	9.0-13.0	...	...	^G	...	Co 0.20, Ta 0.10
TP348H	S34809	0.04-0.10	2.00	0.045	0.030	1.00	17.0-19.0	9.0-13.0	...	...	^H	...	Co 0.20, Ta 0.10
...	S35045	0.06-0.10	1.50	0.045	0.015	1.00	25.0-29.0	32.0-37.0	...	...	...	0.15-0.60	Al 0.15-0.60, Cu 0.75
XM-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	...	...	...	Cu 0.75-1.50, Al 0.30
TP444	S44400	0.03	1.00	0.040	0.030	1.00	17.5-19.5	^I	1.75-2.50	0.035	...	^J	...

^A Maximum, unless a range or minimum is indicated. Where ellipses (...) appear in this table, there is no minimum and analysis for the element need not be determined or reported.

^B The method of analysis for Nitrogen shall be a matter of agreement between the purchaser and the producer.

^C For these alloys, there is no common grade designation. The UNS number uniquely identifies these alloys.

^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 TP304L, TP304LN, TP316L, and TP316LN.

^E Grade S30434 shall have (Ti + 1/2 Nb) of not less than 2 times and not more than 4 times the carbon content.

^F Grade TP347LN shall have an Nb content of not less than 15 times the carbon content.

^G Grade TP348 shall have an Nb + Ta content of not less than 10 times the carbon content and not more than 1.10%.

^H Grade TP348H shall have an Nb + Ta content of not less than 8 times the carbon content and not more than 1.10%.

^I Grade TP444 shall have Ni + Cu = 1.00 max.

^J Grade TP444 shall have Ti + Nb = 0.20 + 4(C + N)-0.80.

TABLE 3 HEAT TREATMENT AND GRAIN SIZE REQUIREMENTS^A

Grade	UNS Number	Heat Treat Type	Austenitizing/ Solutioning Temperature, min or range °F [°C]	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 [650 to 730]	... ... ...
T5	K41545	full or isothermal anneal normalize and temper	... ...	... ...	... 1250 [675]	... ...
T5b	K51545	full or isothermal anneal normalize and temper	... ...	... ...	... 1250 [675]	... ...
T5c	K41245	subcritical anneal	...	air or furnace	1350 [730] ^C	...
T9	S50400	full or isothermal anneal normalize and temper	... ...	... ...	... 1250 [675]	... ...
T11	K11597	full or isothermal anneal normalize and temper	... ...	... ...	... 1200 [650]	... ...
T12	K11562	full or isothermal anneal normalize and temper subcritical anneal	... ... ...	... ... ...	... ... 1200 to 1350 [650 to 730]	... ... ...
T17	K12047	full or isothermal anneal normalize and temper	... ...	... ...	... 1200 [650]	... ...
T21	K31545	full or isothermal anneal normalize and temper	... ...	... ...	... 1250 [675]	... ...
T22	K21590	full or isothermal anneal normalize and temper	... ...	... ...	... 1250 [675]	... ...
T23	K40712	normalize and temper	1900-1975 [1040-1080]	...	1350-1470 [730-800]	...
T24	K30736	normalize and temper	1800-1975 [980-1080]	...	1350-1470 [730-800]	...
T36	K21001	normalize and temper	1650 [900]	^D	1100 [595]	...
T91	K90901	normalize and temper	1900-1975 [1040-1080]	...	1350-1470 [730-800]	...
T92	K92460	normalize and temper	1900-1975 [1040-1080]	...	1350-1470 [730-800]	...
T122	K91261	normalize and temper	1900-1975 [1040-1080]	...	1350-1470 [730-800]	...
T911	K91061	normalize and temper	1900-1975 [1040-1080]	^E	1365-1435 [740-780]	...
Austenitic Stainless Steels						
TP201	S20100	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP202	S20200	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
XM-19	S20910	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
...	S21500	solution treatment	1900[1040] ^{F,G}	water or other rapid cool	...	...
...	S25700	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
...	S30150	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP304	S30400	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP304L	S30403	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP304H	S30409	solution treatment	1900[1040]	water or other rapid cool	...	7
...	S30432	solution treatment	2000[1100] ^F	water or other rapid cool	...	...
...	S30434	solution treatment	2120[1160]	water or other rapid cool	...	...
TP304N	S30451	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP304LN	S30453	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
...	S30615	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
...	S30815	solution treatment	1920[1050]	water or other rapid cool	...	...
TP309S	S30908	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP309H	S30909	solution treatment	1900[1040]	water or other rapid cool	...	7
TP309Cb	S30940	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP309HCb	S30941	solution treatment	1900[1040] ^H	water or other rapid cool	...	7
...	S30942	solution treatment	2120[1160]	water or other rapid cool	...	6
...	S31002	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP310S	S31008	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP310H	S31009	solution treatment	1900[1040]	water or other rapid cool	...	7
...	S31035	solution treatment	2160-2280 [1180-1250]	water or other rapid cool	...	7
TP310Cb	S31040	solution treatment	1900[1040] ^F	water or other rapid cool	...	...
TP310HCb	S31041	solution treatment	1900[1040] ^H	water or other rapid cool	...	7
TP310HCbN	S31042	solution treatment	1900[1040] ^{F,H}	water or other rapid cool	...	7
...	S31060	solution treatment	1975-2160 [1080-1180] ^F	water or other rapid cool	...	7
...	S31254	solution treatment	2100[1150]	water or other rapid cool	...	...
...	S31272	solution treatment	1920[1050]	water or other rapid cool	...	...
...	S31277	solution treatment	2050[1120] ^F	water or other rapid cool	...	...
TP316	S31600	solution treatment	1900[1040] ^F	water or other rapid cool	...	...

TABLE 3 HEAT TREATMENT AND GRAIN SIZE REQUIREMENTS^A (CONT'D)

Grade	UNS Number	Heat Treat Type	Austenitizing/ Solutioning Temperature, min or range °F[°C]	Cooling Media	Subcritical Annealing or Tempering Temperature, min or range °F [°C]	ASTM Grain Size No. ^B
TP316L	S31603	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP316H	S31609	solution treatment	1900 [1040]	water or other rapid cool	...	7
TP316Ti	S31635	solution treatment	1900 [1040]	water or other rapid cool	...	...
TP316N	S31651	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP316LN	S31653	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP317	S31700	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP317L	S31703	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
...	S31725	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
...	S32050	solution treatment	2100 [1150] ^F	water or other rapid cool	...	...
TP321	S32100	solution treatment	1900 [1040] ^{F,H}	water or other rapid cool	...	...
TP321H	S32109	solution treatment	cold worked: 2000 [1090] hot rolled: 1925 [1050] ^H	water or other rapid cool	...	7
...	S32615	solution treatment	1900 [1040] ^F	water or other rapid cool	...	3 or finer
...	S32716	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
...	S33228	solution treatment	2050 [1120]	water or other rapid cool	...	...
...	S34565	solution treatment	2050-2140 [1120-1170]	water or other rapid cool	...	...
TP347	S34700	solution treatment	1900 [1040] ^{F,H}	water or other rapid cool	...	...
TP347H	S34709	solution treatment	cold worked: 2000 [1100] hot rolled: 1925 [1050] ^H	water or other rapid cool	...	7
TP347HFG	S34710	solution treatment, ^I	2150 [1175] ^F	water or other rapid cool	...	7-10
TP347LN	S34751	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
TP348	S34800	solution treatment	1900 [1040] ^{F,H}	water or other rapid cool	...	...
TP348H	S34809	solution treatment	cold worked: 2000 [1100] hot rolled: 1925 [1050] ^H	water or other rapid cool	...	7
...	S35045	solution treatment	2000 [1100] ^F	still air cool or faster	...	...
XM-15	S38100	solution treatment	1900 [1040] ^F	water or other rapid cool	...	...
...	S38815	solution treatment	1950 [1065] ^F	water or other rapid cool	...	...
Ferritic Stainless Steels						
TP444	S44400	subcritical anneal	...	...	1400 [760]	...

^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 air cooling or liquid quenching shall be permitted for Class 2.

^E Accelerated cooling from the normalizing temperature shall be permitted for section thicknesses greater than 3 in. [75 mm].

^F Quenched in water or rapidly cooled by other means, at a rate sufficient to prevent re-precipitation of carbides, as demonstrable by the capability of tubes, heat treated by either separate solution annealing or by direct quenching, passing Practices A 262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (see Supplementary Requirement S4). Note that Practices A 262 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 for 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 the purchaser.

^G A maximum solution treating temperature of 2100 °F [1150 °C] is recommended for UNS S21500.

^H 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.

^I 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
<i>Low Alloy Steels:</i>						
T5b	K51545	60 [415]	30 [205]	30	179 HBW/ 190HV	89 HRB
T9	K90941	60 [415]	30 [205]	30	179 HBW/ 190HV	89 HRB
T12	K11562	60 [415]	32 [220]	30	163 HBW/ 170 HV	85 HRB
T23	K40712	74 [510]	58 [400]	20	220 HBW/ 230 HV	97 HRB
T24	K30736	85 [585]	60 [415]	20	250 HBW/ 265 HV	25 HRC
T36 Class 1	K21001	90 [620]	64 [440]	15	250 HBW/ 265 HV	25 HRC
T36 Class 2	K21001	95.5 [660]	66.5 [460]	15	250 HBW/ 265 HV	25 HRC
T91	K90901	85 [585]	60 [415]	20	250 HBW/ 265 HV	25 HRC
T92	K92460	90 [620]	64 [440]	20	250 HBW/ 265 HV	25 HRC
T122	K91271	90 [620]	58 [400]	20	250 HBW/ 265 HV	25 HRC
T911	K91061	90 [620]	64 [440]	20	250 HBW/ 265 HV	25 HRC
All other low alloy grades		60 [415]	30 [205]	30	163 HB/ 170 HV	85 HRB
<i>Austenitic Stainless Steels:</i>						
TP201	S20100	95 [655]	38 [260]	35	219 HBW/ 230 HV	95 HRB
TP202	S20200	90 [620]	45 [310]	35	219 HBW/ 230 HV	95 HRB
XM-19	S20910	100 [690]	55 [380]	35	250 HBW/ 265 HV	25 HRC
...	S21500	78 [540]	33 [230]	35	192 HBW/ 200 HV	90 HRB
...	S25700	78 [540]	35 [240]	50	217 HBW	95 HRB
TP304	S30400	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP304L	S30403	70 [485]	25 [170]	35	192 HBW/ 200 HV	90 HRB
TP304H	S30409	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S30432	86 [590]	34 [235]	35	219 HBW/ 230 HV	95 HRB
...	S30434	73 [500]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP304N	S30451	80 [550]	35 [240]	35	192 HBW/ 200 HV	90 HRB
TP304LN	S30453	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S30615	90 [620]	40 [275]	35	192 HBW/ 200 HV	90 HRB
...	S30815	87 [600]	45 [310]	40	217 HBW	95 HRB
TP309S	S30908	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB

TABLE 4 TENSILE AND HARDNESS REQUIREMENTS (CONT'D)

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
TP309H	S30909	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP309Cb	S30940	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP309HCb	S30941	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S30942	86 [590]	34 [235]	35	219 HBW/ 230 HV	95 HRB
...	S31002	73 [500]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP310S	S31008	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP310H	S31009	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S31035	95 [655]	45 [310]	40	220 HBW/ 230 HV	96 HRB
TP310Cb	S31040	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP31010HCb	S31041	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP310HCbN	S31042	95 [655]	43 [295]	30	256 HBW	100 HRB
TP310MoLN	S31050					
T ≤ 0.25 in. [6 mm]		84 [580]	39 [270]	25	217 HBW	95 HRB
t > 0.25 in. [6 mm]		78 [540]	37 [255]	25	217 HBW	95 HRB
...	S31060	87 [600]	41 [280]	40	217 HBW	95 HRB
...	S31254					
T ≤ 0.187 in. [5 mm]		98 [675]	45 [310]	35	220 HBW/ 230 HV	96 HRB
T > 0.187 in. [5 mm]		95 [655]	45 [310]	35	220 HBW/ 230 HV	96 HRB
...	S31272	65 [450]	29 [200]	35	217 HBW	95 HRB
...	S31277	112 [770]	52 [360]	40	241 HBW	100 HRB
TP316	S31600	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP316L	S31603	70 [485]	25 [170]	35	192 HBW/ 200 HV	90 HRB
TP316H	S31609	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP316Ti	S31635	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP316N	S31651	80 [550]	35 [240]	35	192 HBW/ 200 HV	90 HRB
TP317	S31700	75 [515]	30 [205]	34	192 HBW/ 200 HV	90 HRB
TP317L	S31703	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S31725	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S32050	98 [675]	48 [330]	40	256 HBW	100 HRB
TP321	S32100	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB

TABLE 4 TENSILE AND HARDNESS REQUIREMENTS (CONT'D)

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
TP321H	S32109	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S32615	80 [550]	32 [220]	25	192 HBW/ 200 HV	90 HRB
...	S32716	80 [550]	35 [240]	35	192 HBW/ 200 HV	90 HRB
...	S33228	73 [500]	27 [185]	30	192 HBW/ 200 HV	90 HRB
...	S34565	115 [790]	60 [415]	35	241 HBW	100 HRB
TP347	S34700	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP347H	S34709	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP347HFG	S34710	80 [550]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP347LN	S34751	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP348	S34800	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP348H	S34809	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S35045	70 [485]	25 [170]	35	192 HBW/ 200 HV	90 HRB
XM-15	S38100	75 [515]	30 [205]	35	192 HBW/ 200 HV	90 HRB
...	S38815	78 [540]	37 [255]	30	256 HBW	100 HRB
<i>Ferritic Stainless Steels</i>						
TP444	S44400	60 [415]	40 [275]	20	217 HBW/ 230 HV	96 HRB

^A When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimens with gage length equal to 4D (4 times the diameter) is used, the minimum elongation shall be 22% for all low alloy grades except T23, T24, T91, T92, T122, and T911; and except for TP444.

^B For longitudinal strip tests, a deduction from the basic minimum elongation values of 1.00% for TP444, T23, T24, T91, T92, T122, and T911, and of 1.50% for all other low alloy grades for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] shall be made.

TABLE 5
COMPUTED MINIMUM VALUES [NOTE (1)]

Wall Thickness		Elongation in 2 in. or 50 mm, Min., %		
		S44400, T23, T24, T91, T92, T122, and T911		All Other Ferritic Grades
in.	mm	T36	T36	
$\frac{5}{16}$ [0.312]	8	20	15	30
$\frac{9}{32}$ [0.281]	7.2	19	14	29
$\frac{1}{4}$ [0.250]	6.4	18	13	27
$\frac{7}{32}$ [0.219]	5.6	17	12	26
$\frac{3}{16}$ [0.188]	4.8	16	11	24
$\frac{5}{32}$ [0.156]	4	15	10	23
$\frac{1}{8}$ [0.125]	3.2	14	9	21
$\frac{3}{32}$ [0.094]	2.4	13	8	20
$\frac{1}{16}$ [0.062]	1.6	12	7	18
0.062 to 0.035, excl.	1.6 to 0.9	12	7	17
0.035 to 0.022, excl.	0.9 to 0.6	11	6	17
0.022 to 0.015 incl.	0.6 to 0.4	11	6	16

NOTE:

- (1) 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

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 chloride 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 4 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.