



# Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes<sup>1</sup>

This standard is issued under the fixed designation A213/A213M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the U.S. Department of Defense.*

## 1. Scope\*

1.1 This specification<sup>2</sup> 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 SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the “M” designation of this specification is specified in the order.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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

Current edition approved May 1, 2022. Published May 2022. Originally approved in 1939. Last previous edition approved in 2021 as A213/A213M – 21b. DOI: 10.1520/A0213\_A0213M-22.

<sup>2</sup> For ASME Boiler and Pressure Vessel Code applications see related Specification SA-213 in Section II of that Code.

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>3</sup>

[A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels](#)

[A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys](#)

[A1016/A1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes](#)

[E112 Test Methods for Determining Average Grain Size](#)

### 2.2 AWS Specifications<sup>4</sup>

[A5.5/A5.5M Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding](#)

[A5.23/A5.23M Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding](#)

[A5.28/A5.28M Specification for Low-Alloy Steel Electrodes for Gas Shielded Arc Welding](#)

[A5.29/A5.29M Low-Alloy Steel Electrodes for Flux Cored Arc Welding](#)

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology [A941](#).

## 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 Heat treatment type ([Table 3](#)).

4.1.6 Controlled structural characteristics (see [6.3](#)),

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard’s Document Summary page on the ASTM website.

<sup>4</sup> Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, <http://www.aws.org>.

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

TABLE 1 Chemical Composition Limits, %<sup>A</sup>, for Low Alloy Steel

| Grade      | UNS Designation | Composition, % |                        |                    |                    |                        |                   |                      |            |           |                    |                          |                    |                   | Other Elements |  |  |
|------------|-----------------|----------------|------------------------|--------------------|--------------------|------------------------|-------------------|----------------------|------------|-----------|--------------------|--------------------------|--------------------|-------------------|----------------|--|--|
|            |                 | Carbon         | Manganese              | Phosphorus         | Sulfur             | Silicon                | Nickel            | Chromium             | Molybdenum | Vanadium  | Boron              | Niobium <sup>F</sup>     | Nitrogen           | Aluminum          |                | Tungsten   |  |
| T2         | K11547          | 0.10-0.20      | 0.30-0.61              | 0.025              | 0.025 <sup>B</sup> | 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<br>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 <sup>B</sup> | 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                   | 0.40              | 1.90-2.60            | 0.05-0.30  | 0.20-0.30 | 0.0010-0.006       | 0.015                    | 0.030              | 1.45-1.75         | 0.005-0.060    | Ti 0.005-0.060   |  |
| 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               | ...               | ...            | Ti/N $\geq$ 3.5 <sup>C</sup>   |  |
| 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              | 0.050              | ...               | ...            | Ti<br>Cu<br>0.06-0.10  |  |
| T91 Type 1 | 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 | ...                | 0.030-0.070              | 0.02               | ...               | ...            | Ti 0.01<br>Zr 0.01<br>Cu 0.10 <sup>D</sup><br>Sb<br>0.003 <sup>D</sup><br>Sn<br>0.010 <sup>D</sup><br>As<br>0.010 <sup>D</sup><br>N/Al 4.0 min |  |
| T91 Type 2 | K90901          | 0.08-0.12      | 0.30-0.50 <sup>D</sup> | 0.020 <sup>D</sup> | 0.005 <sup>D</sup> | 0.20-0.40 <sup>D</sup> | 0.20 <sup>D</sup> | 8.0-9.5 <sup>D</sup> | 0.85-1.05  | 0.18-0.25 | 0.001 <sup>D</sup> | 0.035-0.070 <sup>D</sup> | 0.020 <sup>D</sup> | 0.05 <sup>D</sup> | ...            | ...  | Ti 0.01 <sup>D</sup><br>Zr 0.01 <sup>D</sup><br>Cu 0.10 <sup>D</sup><br>Sb<br>0.003 <sup>D</sup><br>Sn<br>0.010 <sup>D</sup><br>As<br>0.010 <sup>D</sup><br>N/Al 4.0 min |
| Product    |                 | 0.07-0.13      |                        |                    |                    |                        |                   | 0.80-1.05            | 0.16-0.27  |           | 0.05-0.11          |                          |                    |                   |                |  | Ti 0.01<br>Zr 0.01<br>Cu 0.10<br>As 0.010<br>Sn 0.010<br>Sb 0.003<br>W 0.05<br>N/Al 4.0 min<br>CNB <sup>G</sup><br>10.5 max  |
| 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        | 0.030-0.070              | 0.02               | 1.5-2.00          | ...            | ...  | ...  |
| T93        | K91350          | 0.05-0.10      | 0.20-0.70              | 0.020              | 0.008              | 0.05-0.50              | 0.20              | 8.50-9.50            | ...        | 0.15-0.30 | 0.007-0.015        | F<br>0.005-0.015         | 0.030              | 2.5-3.5           | ...            | ...  | ...  |
| T115 Heat  | K91060          | 0.08-0.13      | 0.20-0.50              | 0.020              | 0.005              | 0.15-0.45              | 0.25              | 10.0-11.0            | 0.40-0.60  | 0.18-0.25 | 0.001              | 0.030-0.070              | 0.02               | ...               | ...            | ...  | ...  |



TABLE 1 Continued

| Grade   | UNS Designation | Composition, % |             |            |        |             |             |               |             |             |               |                      | Tungsten      | Other Elements |             |   |
|---------|-----------------|----------------|-------------|------------|--------|-------------|-------------|---------------|-------------|-------------|---------------|----------------------|---------------|----------------|-------------|---|
|         |                 | Carbon         | Manganese   | Phosphorus | Sulfur | Silicon     | Nickel      | Chromium      | Molybdenum  | Vanadium    | Boron         | Niobium <sup>E</sup> |               |                | Nitrogen    | Aluminum  |
| Product |                 | 0.07–0.14      | 0.20–0.50   | 0.020      | 0.005  | 0.15–0.45   | 0.25        | 10.0–11.0     | 0.37–0.63   | 0.16–0.27   | 0.001         | 0.02–0.07            | 0.030–0.070   | 0.02           | ...         | Ti 0.01   |
| 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   | Zr 0.01<br>Cu 0.10<br>As 0.010<br>Sn 0.010<br>Sb 0.003<br>W 0.05<br>Cu<br>0.30–1.70 |
| T128    | K91421          | 0.12 – 0.17    | 0.30 – 0.80 | 0.02       | 0.01   | 0.20 – 0.60 | 0.10 – 0.40 | 10.50 – 12.00 | 0.20 – 0.60 | 0.15 – 0.30 | 0.008 – 0.015 | 0.02 – 0.06          | 0.002 – 0.020 | 0.02           | 1.50 – 2.20 | Zr 0.01<br>Co 1.50 – 2.20   |
| 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   | Cu 0.15<br>Ti 0.01<br>Zr 0.01   |
| T921    | K91201          | 0.08–0.12      | 0.5–0.7     | 0.03       | 0.02   | 1.6–2.2     | 0.8–1.4     | 8.0–9.5       | 0.8–1.1     | ...         | ...           | ...                  | 0.02–0.05     | 0.04           | ...         | Cu<br>0.8–1.4   |

<sup>A</sup> 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.

<sup>B</sup> It is permissible to order T2 and T12 with a sulfur content of 0.045 max. See 16.3.

<sup>C</sup> Alternatively, in lieu of this ratio minimum, the material shall have a minimum hardness of 275 HV in the hardened condition, defined as after austenitizing and cooling to room temperature but prior to tempering. Hardness testing shall be performed at mid-thickness of the product. Hardness test frequency shall be two samples of product per heat treatment lot and the hardness testing results shall be reported on the material test report.

<sup>D</sup> Applies to both heat and product analyses.

<sup>E</sup> The terms Niobium (Nb) and Columbium (Cb) are alternate names for the same element.

<sup>F</sup> Grade T93 shall have a Nb + Ta content of 0.05–0.12 %.

<sup>G</sup> Chromium-Nickel Balance is defined as CNB = (Cr + 6Si) + 4Mo + 1.5W + 11V + 5Nb + 9Ti + 12Al) – (40C + 30N + 4Ni + 2Mn + 1Cu).



TABLE 2 Chemical Composition Limits, %<sup>A</sup>, for Austenitic and Ferritic Stainless Steel

| Grade        | UNS Designation | Composition        |           |            |        |           |           |           |            |                       |                        |                        | Other Elements   |
|--------------|-----------------|--------------------|-----------|------------|--------|-----------|-----------|-----------|------------|-----------------------|------------------------|------------------------|--|
|              |                 | Carbon             | Manganese | Phosphorus | Sulfur | Silicon   | Chromium  | Nickel    | Molybdenum | Nitrogen <sup>B</sup> | Niobium <sup>M</sup>   | Titanium               |  |
| 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  |
| <sup>C</sup> | 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,<br>V 0.15-0.40                          |
| <sup>C</sup> | 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 <sup>D</sup> | 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  | ...        | ...                   | ...                    | ...                    | ...  |
| <sup>C</sup> | 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,<br>B 0.001-0.010,<br>Cu 2.5-3.5        |
| <sup>C</sup> | 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 <sup>E</sup> | 0.10-0.25 <sup>F</sup> | B 0.001-0.004<br>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 <sup>D</sup> | 2.00      | 0.045      | 0.030  | 1.00      | 18.0-20.0 | 8.0-11.0  | ...        | 0.10-0.16             | ...                    | ...                    | ...  |
| <sup>C</sup> | 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   |
| <sup>C</sup> | 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 | ...        | ...                   | ...                    | ...                    | ...  |
| TP309LMn     | S30925          | 0.025              | 2.00      | 0.040      | 0.030  | 0.70      | 23.0-26.0 | 13.0-16.0 | 0.5-1.2    | 0.25-0.40             | ...                    | ...                    | ...  |
| 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  |
| <sup>C</sup> | S31002          | 0.015              | 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 | ...        | ...                   | ...                    | ...                    | ...  |
| TP310MoCbN   | S31025          | 0.10               | 1.50      | 0.030      | 0.030  | 1.00      | 19.5-23.0 | 23.0-26.0 | 1.0-2.0    | 0.10-0.25             | 0.10-0.40              | 0.20                   | B 0.002-0.010  |
| ...          | S31035          | 0.04-0.10          | 0.60      | 0.025      | 0.015  | 0.40      | 21.5-23.5 | 23.5-26.5 | ...        | 0.20-0.30             | 0.40-0.60              | ...                    | W 3.0-4.0<br>Co 1.0-2.0<br>Cu 2.5-3.5<br>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              | ...                    | ...  |
| <sup>C</sup> | S31043          | 0.04-0.10          | 2.00      | 0.045      | 0.030  | 1.00      | 24.0-26.0 | 19.0-22.0 | ...        | 0.15-0.35             | 0.20-0.50 <sup>G</sup> | ...                    | Ta 0.20 min <sup>G</sup>                               |
| 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             | ...                    | ...                    | Ce + La<br>0.025-0.070                                 |
| <sup>C</sup> | 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             | ...                    | ...                    | B 0.001-0.010<br>Cu 0.50-1.00                          |
| <sup>C</sup> | 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             | ...                    | ...                    | ...  |



TABLE 2 Continued

| Grade    | UNS Designation | Composition              |           |            |        |           |           |           |            |                       |                        |           | Other Elements                               |
|----------|-----------------|--------------------------|-----------|------------|--------|-----------|-----------|-----------|------------|-----------------------|------------------------|-----------|--|
|          |                 | Carbon                   | Manganese | Phosphorus | Sulfur | Silicon   | Chromium  | Nickel    | Molybdenum | Nitrogen <sup>B</sup> | Niobium <sup>M</sup>   | Titanium  |  |
| ...      | 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             | ...                    | ...       | Cu 1.00-2.00<br>W 1.50-2.50<br>B 0.004-0.008 |
| 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 | 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 <sup>D</sup>       | 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<br>(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 <sup>D</sup>       | 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    | ...                   | ...                    | ...       | ...  |
| 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        | S31730          | 0.030                    | 2.00      | 0.040      | 0.010  | 1.00      | 17.0-19.0 | 15.0-16.5 | 3.0-4.0    | 0.045                 | ...                    | ...       | Cu 4.0-5.0                                   |
| C        | S31740          | 0.005-0.020 <sup>F</sup> | 2.00      | 0.045      | 0.030  | 1.00      | 17.0-19.0 | 11.0-15.0 | 3.0-4.5    | 0.06-0.15             | 0.20-0.50 <sup>F</sup> | ...       | ...  |
| 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,<br>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             | ...                    | ...       | ...  |
| TP347W   | S34705          | 0.05                     | 2.00      | 0.040      | 0.030  | 1.00      | 17.0-20.0 | 8.00-11.0 | ...        | 0.10-0.25             | 0.25-0.50              | ...       | V 0.20-0.50<br>W 1.50-2.60                   |
| 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 | 9.0-13.0  | ...        | 0.06-0.10             | 0.20-0.50 <sup>F</sup> | ...       | ...  |
| C        | S34752          | 0.005-0.020              | 2.00      | 0.035      | 0.010  | 0.60      | 17.0-19.0 | 10.0-13.0 | 0.20-1.20  | 0.06-0.12             | 0.20-0.50 <sup>F</sup> | ...       | Cu 2.50-3.50<br>B 0.001-0.005                |
| TP348    | S34800          | 0.08                     | 2.00      | 0.045      | 0.030  | 1.00      | 17.0-19.0 | 9.0-13.0  | ...        | ...                   | G<br>Co 0.20, Ta 0.10  | ...       | 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<br>Co 0.20, Ta 0.10  | ...       | 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<br>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<br>Al 0.30                      |
| 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  | ...                   | M<br>Cu 3.00-4.00      | ...       | Cu 3.00-4.00                                 |
|          | N08028          | 0.030                    | 2.50      | 0.030      | 0.030  | 1.0       | 26.0-28.0 | 30.0-34.0 | 3.0-4.0    | ...                   | ...                    | ...       | Cu 0.6-1.4                                   |
|          | N08029          | 0.020                    | 2.0       | 0.025      | 0.015  | 0.6       | 26.0-28.0 | 30.0-34.0 | 4.0-5.0    | ...                   | ...                    | ...       | Cu 0.6-1.4                                   |



TABLE 2 Continued

| Grade    | UNS Designation | Composition |            |             |        |         |           |                        |            |                       |                      |                  | Other Elements  |
|----------|-----------------|-------------|------------|-------------|--------|---------|-----------|------------------------|------------|-----------------------|----------------------|------------------|---|
|          |                 | Carbon      | Manga-nese | Phospho-rus | Sulfur | Silicon | Chromium  | Nickel                 | Molybdenum | Nitrogen <sup>B</sup> | Niobium <sup>N</sup> | Titanium         |   |
| C<br>800 | N08367          | 0.030       | 2.00       | 0.040       | 0.030  | 1.00    | 20.0-22.0 | 23.5-25.5              | 6.00-7.00  | 0.18-0.25             | ...                  | ...              | Cu 0.75<br>Cu 0.75  |
|          | N08800          | 0.10        | 1.50       | 0.045       | 0.015  | 1.00    | 19.0-23.0 | 30.0-35.0              | ...        | ...                   | ...                  | ...              | Al 0.15-0.60<br>Ti 0.15-0.60<br>Fe <sup>L</sup> 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              | ...        | ...                   | ...                  | ...              | Cu 0.75<br>Al 0.15-0.60<br>Ti 0.15-0.60<br>Fe <sup>L</sup> 39.5 min                           |
| ...      | N08811          | 0.06-0.10   | 1.50       | 0.045       | 0.015  | 1.00    | 19.0-23.0 | 30.0-35.0              | ...        | ...                   | ...                  | ...              | Cu 0.75<br>Al 0.15-0.60 <sup>J</sup><br>Ti 0.15-0.60 <sup>J</sup><br>Fe <sup>L</sup> 39.5 min |
| ...      | 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                  | ...                  | ...              | Cu 1.00-2.00  |
| ...      | N08925          | 0.020       | 1.00       | 0.045       | 0.030  | 0.50    | 19.0-21.0 | 24.0-26.0              | 6.0-7.0    | 0.10-0.20             | ...                  | ...              | Cu 0.80-1.50  |
| ...      | 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             | ...                  | ...              | Cu 0.50-1.50  |
| TP444    | S44400          | 0.03        | 1.00       | 0.040       | 0.030  | 1.00    | 17.5-19.5 | <sup>K</sup> 30.0-35.0 | 1.75-2.50  | 0.035                 | ...                  | <sup>L</sup> ... | ...   |

<sup>A</sup>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.

<sup>B</sup>The method of analysis for Nitrogen shall be a matter of agreement between the purchaser and the producer.

<sup>C</sup>For these alloys, there is no common grade designation. The UNS number uniquely identifies these alloys.

<sup>D</sup>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.

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

<sup>F</sup>Grade TP347LN and S34752 shall have an Nb content of not less than 15 times the carbon content.

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

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

<sup>I</sup>Iron shall be determined arithmetically by difference of 100 minus the sum of the other specified elements.

<sup>J</sup>Al + Ti shall be 0.85 % min; 1.20 % max.

<sup>K</sup>Grade TP444 shall have Ni + Cu = 1.00 max.

<sup>L</sup>Grade TP444 shall have Ti + Nb content not less than 0.20 + 4(C+N) and not more than 0.80 %.

<sup>M</sup>N08020 shall have an Nb + Ta content of not less than 8 times the carbon content and not more than 1.00%.

<sup>N</sup>The terms Niobium (Nb) and Columbium (Cb) are alternative names for the same element.

<sup>O</sup>UNS S31043 shall have a Nb + 1/2Ta content of 0.30 to 0.60 %.

<sup>P</sup>UNS designation S31740 steel shall have a niobium content of not less than 15 times the carbon content.

**TABLE 3 Heat Treatment and Grain Size Requirements<sup>A</sup>**

| Grade                              | UNS Number | Heat Treat Type   | Austenitizing/<br>Solutioning/<br>Stabilizing<br>Temperature,<br>min or range °F [°C] | Cooling Media             | Subcritical Annealing<br>or Tempering<br>Temperature,<br>min or range °F [°C] | ASTM<br>Grain Size No. <sup>B</sup> |
|------------------------------------|------------|---|---|---------------------------|---|-------------------------------------|
| <b>Ferritic Alloy Steels</b>       |            |   |   |                           |   |                                     |
| T2                                 | K11547     | full or isothermal<br>anneal; or<br>normalize and<br>temper; or<br>subcritical anneal | ...   | ...                       | 1200 to 1350<br>[650 to 730]  | ...                                 |
| T5                                 | K41545     | full or isothermal<br>anneal; or<br>normalize and<br>temper                           | ...   | ...                       | 1250 [675]  | ...                                 |
| T5b                                | K51545     | full or isothermal<br>anneal; or<br>normalize and<br>temper                           | ...   | ...                       | 1250 [675]  | ...                                 |
| T5c                                | K41245     | subcritical anneal  | ...   | air or furnace            | 1350 [730] <sup>C</sup>   | ...                                 |
| T9                                 | S50400     | full or isothermal<br>anneal; or<br>normalize and<br>temper                           | ...   | ...                       | 1250 [675]  | ...                                 |
| T11                                | K11597     | full or isothermal<br>anneal; or<br>normalize and<br>temper                           | ...   | ...                       | 1200 [650]  | ...                                 |
| T12                                | K11562     | full or isothermal<br>anneal; or<br>normalize and<br>temper; or<br>subcritical anneal | ...   | ...                       | 1200 to 1350<br>[650 to 730]  | ...                                 |
| T17                                | K12047     | full or isothermal<br>anneal; or<br>normalize and<br>temper                           | ...   | ...                       | 1200 [650]  | ...                                 |
| T21                                | K31545     | full or isothermal<br>anneal; or<br>normalize and<br>temper                           | ...   | ...                       | 1250 [675]  | ...                                 |
| T22                                | K21590     | full or isothermal<br>anneal; or<br>normalize and<br>temper                           | ...   | ...                       | 1250 [675]  | ...                                 |
| T23                                | K40712     | normalize and<br>temper   | 1900–1975<br>[1040–1080]  | ...                       | 1350–1470 [730–800]   | ...                                 |
| T24                                | K30736     | normalize and<br>temper   | 1800–1870<br>[980–1020]   | <i>D</i>                  | 1350–1420 [730–770]   | ...                                 |
| T36                                | K21001     | normalize and<br>temper   | 1650 [900]  | <i>E</i>                  | 1100 [595]  | ...                                 |
| T91 Types 1 and 2                  | K90901     | normalize and<br>temper   | 1900–1975<br>[1040–1080]  | ...                       | 1350–1470 [730–800]   | ...                                 |
| T92                                | K92460     | normalize and<br>temper   | 1900–1975<br>[1040–1080]  | ...                       | 1350–1470 [730–800]   | ...                                 |
| T93                                | K91350     | normalize and<br>temper   | 1960–2140<br>[1070–1170]  | ...                       | 1380–1455 [750–790]   | ...                                 |
| T115                               | K91060     | normalize and<br>temper   | 1920–2010<br>[1050–1100]  | ...                       | 1380–1455<br>[750–790]  | ...                                 |
| T122                               | K91261     | normalize and<br>temper   | 1900–1975<br>[1040–1080]  | ...                       | 1350–1470 [730–800]   | ...                                 |
| T128                               | K91421     | normalize and<br>temper   | 1975–2140<br>[1080–1170]  | air                       | 1400–1470<br>[760–800]  | ...                                 |
| T911                               | K91061     | normalize and<br>temper   | 1900–1975<br>[1040–1080]  | <i>D</i>                  | 1365–1435<br>[740–780]  | ...                                 |
| T921                               | K91201     | normalize and<br>temper   | 1670–1740<br>[910–950]  | air                       | 1350–1420<br>[730–770]  | ...                                 |
| <b>Austenitic Stainless Steels</b> |            |   |   |                           |   |                                     |
| TP201                              | S20100     | solution treatment  | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP202                              | S20200     | solution treatment  | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| XM-19                              | S20910     | solution treatment  | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|                                    | S21500     | solution treatment  | 1900 [1040] <sup>F,G</sup>  | water or other rapid cool | ...   | ...                                 |
|                                    | S25700     | solution treatment  | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP304                              | S30400     | solution treatment  | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |



TABLE 3 Continued

| Grade      | UNS Number | Heat Treat Type                  | Austenitizing/<br>Solutioning/<br>Stabilizing<br>Temperature,<br>min or range °F [°C] | Cooling Media             | Subcritical Annealing<br>or Tempering<br>Temperature,<br>min or range °F [°C] | ASTM<br>Grain Size No. <sup>B</sup> |
|------------|------------|----------------------------------|---|---------------------------|---|-------------------------------------|
| TP304L     | S30403     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP304H     | S30409     | solution treatment               | 1900 [1040]   | water or other rapid cool | ...   | 7                                   |
|            | S30432     | solution treatment               | 2000 [1100] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|            | S30434     | solution treatment               | 2120 [1160]   | water or other rapid cool | ...   | ...                                 |
| TP304N     | S30451     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP304LN    | S30453     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|            | S30615     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|            | S30815     | solution treatment               | 1920 [1050]   | water or other rapid cool | ...   | ...                                 |
| TP309S     | S30908     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP309H     | S30909     | solution treatment               | 1900 [1040]   | water or other rapid cool | ...   | 7                                   |
| TP309LMoN  | S30925     | solution treatment               | 1920 [1050]   | water or other rapid cool | ...   | 7                                   |
| TP309Cb    | S30940     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP309HCb   | S30941     | solution treatment               | 1900 [1040] <sup>H</sup>  | water or other rapid cool | ...   | 7                                   |
|            | S30942     | solution treatment               | 2120 [1160]   | water or other rapid cool | ...   | 6                                   |
|            | S31002     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP310S     | S31008     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP310H     | S31009     | solution treatment               | 1900 [1040]   | water or other rapid cool | ...   | 7                                   |
| TP310MoCbN | S31025     | solution treatment               | 2100 [1150]   | water or other rapid cool | ...   | 7                                   |
|            | S31035     | solution treatment               | 2160–2280<br>[1180–1250]  | water or other rapid cool | ...   | ...                                 |
| TP310Cb    | S31040     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP310HCb   | S31041     | solution treatment               | 1900 [1040] <sup>H</sup>  | water or other rapid cool | ...   | 7                                   |
| TP310HCbN  | S31042     | solution treatment               | 1900 [1040] <sup>F,H</sup>  | water or other rapid cool | ...   | 7                                   |
| ...        | S31043     | solution treatment               | 1900 [1040] <sup>F,H</sup>  | water or other rapid cool | ...   | 7                                   |
| TP310MoLN  | S31050     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|            | S31060     | solution treatment               | 1975–2160<br>[1080–1180] <sup>F</sup>   | water or other rapid cool | ...   | 7                                   |
|            | S31254     | solution treatment               | 2100 [1150]   | water or other rapid cool | ...   | ...                                 |
|            | S31266     | solution treatment               | 2100 [1150]   | water or other rapid cool | ...   | ...                                 |
|            | S31272     | solution treatment               | 1920 [1050]   | water or other rapid cool | ...   | ...                                 |
|            | S31277     | solution treatment               | 2050 [1120] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP316      | S31600     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP316L     | S31603     | solution treatment               | 1900 [1040] <sup>F</sup>  | 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] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP316LN    | S31653     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP317      | S31700     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP317L     | S31703     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|            | S31725     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|            | S31730     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|            | S31740     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|            | S32050     | solution treatment               | 2100 [1150] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
| TP321      | S32100     | solution treatment               | 1900 [1040] <sup>F,H</sup>  | water or other rapid cool | ...   | ...                                 |
| TP321H     | S32109     | solution treatment               | cold worked:<br>2000 [1090]<br>hot rolled:<br>1925 [1050] <sup>H</sup>                | water or other rapid cool | ...   | 7                                   |
|            | S32615     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | 3 or finer                          |
|            | S32716     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|            | S33228     | solution treatment               | 2050 [1120]   | water or other rapid cool | ...   | ...                                 |
|            | S34565     | solution treatment               | 2050–2140<br>[1120–1170]  | water or other rapid cool | ...   | ...                                 |
| TP347      | S34700     | solution treatment               | 1900 [1040] <sup>F,H</sup>  | water or other rapid cool | ...   | ...                                 |
| TP347W     | S34705     | solution treatment               | 2000 [1100]   | water or other rapid cool | ...   | 7-10                                |
| TP347H     | S34709     | solution treatment               | cold worked:<br>2000 [1100]<br>hot rolled:<br>1925 [1050] <sup>H</sup>                | water or other rapid cool | ...   | 7                                   |
| TP347HFG   | S34710     | solution treatment, <sup>1</sup> | 2150 [1175] <sup>F</sup>  | water or other rapid cool | ...   | 7-10                                |
| TP347LN    | S34751     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|            | S34752     | solution treatment               | 1940–2138<br>[1060–1170]  | Water or other rapid cool | ...   | ...                                 |
| TP348      | S34800     | solution treatment               | 1900 [1040] <sup>F,H</sup>  | water or other rapid cool | ...   | ...                                 |
| TP348H     | S34809     | solution treatment               | cold worked:<br>2000 [1100]<br>hot rolled:<br>1925 [1050] <sup>H</sup>                | water or other rapid cool | ...   | 7                                   |
|            | S35045     | solution treatment               | 2000 [1100] <sup>F</sup>  | still air cool or faster  | ...   | ...                                 |
| XM-15      | S38100     | solution treatment               | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|            | S38815     | solution treatment               | 1950 [1065] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |



**TABLE 3** *Continued*

| Grade                       | UNS Number | Heat Treat Type         | Austenitizing/<br>Solutioning/<br>Stabilizing<br>Temperature,<br>min or range °F [°C] | Cooling Media             | Subcritical Annealing<br>or Tempering<br>Temperature,<br>min or range °F [°C] | ASTM<br>Grain Size No. <sup>B</sup> |
|-----------------------------|------------|-------------------------|---|---------------------------|---|-------------------------------------|
| Alloy 20<br><br>800<br>800H | N08020     | stabilization treatment | 1700-1850 [925-1010] <sup>F</sup>   | water or other rapid cool | ...   | ...                                 |
|                             | N08028     | solution treatment      | 2000 [1100] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|                             | N08029     | solution treatment      | 2000 [1100] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|                             | N08367     | solution treatment      | 2025 [1105] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|                             | N08800     | solution treatment      | 1900 [1040] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|                             | N08810     | solution treatment      | 2050 [1120] <sup>F</sup>  | water or other rapid cool | ...   | 5                                   |
|                             | N08811     | solution treatment      | 2100 [1150] <sup>F</sup>  | water or other rapid cool | ...   | 5                                   |
|                             | N08904     | solution treatment      | 2000 [1100] <sup>F</sup>  | water or other rapid cool | ...   | ...                                 |
|                             | N08925     | solution treatment      | 2010–2100 [1100–1150]   | water or other rapid cool | ...   | ...                                 |
|                             | N08926     | solution treatment      | 2010–2100 [1100–1150]   | water or other rapid cool | ...   | ...                                 |
| Ferritic Stainless Steels   |            |                         |   |                           |   |                                     |
| TP444                       | S44400     | subcritical anneal      | ...   | ...                       | 1400 [760]  | ...                                 |

<sup>A</sup> Where ellipses (...) appear in this table there is no requirement.

<sup>B</sup> ASTM Grain Size No. listed, or coarser, unless otherwise indicated.

<sup>C</sup> Approximately, to achieve properties.

<sup>D</sup> Accelerated cooling from the normalizing temperature shall be permitted for section thicknesses greater than 3 in. [75 mm].

<sup>E</sup> Accelerated air cooling or liquid quenching shall be permitted for Class 2.

<sup>F</sup> 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 A262, 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 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 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.

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

<sup>H</sup> 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.

<sup>I</sup> 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.

4.1.7 Size (outside diameter and minimum wall thickness, unless average wall thickness is specified),

4.1.8 Length (specific or random),

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

4.1.10 Specification designation and year of issue,

4.1.11 Increased sulfur (for machinability, see Note B, Table 1, and 16.3), and

4.1.12 Special requirements and any supplementary requirements selected.

## 5. General Requirements

5.1 Product furnished to this specification shall conform to the requirements of Specification A1016/A1016M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A1016/A1016M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A1016/A1016M, 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 minimum solution or stabilization treatment temperature specified in Table 3, tubes may be individually quenched in water or rapidly cooled by other means (direct quenched).

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 [E112](#).

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 [15.1](#).

## 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, T115, T122, T128, T911, T921, and S44400:  $E = 32t + 10.00$  [ $E = 1.25t + 10.00$ ]. For Grade T36:  $E = 32t + 5.0$  [ $E = 1.25t + 5.0$ ]. For grade T93:  $E = 32t + 9.00$  [ $E = 1.25t + 9.00$ ]. 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 [15.2](#).

### 9.2 Hardness Requirements:

9.2.1 The material shall conform to the hardness requirements given in [Table 4](#). See [15.2](#).

9.2.2 Brinell, Vickers, or Rockwell hardness tests shall be made on specimens from two tubes from each lot. See [15.2](#).

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 [15.1](#).

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 [15.1](#).

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. Repair by Welding

12.1 Repair welding shall be performed in conformance with Specification [A1016/A1016M](#).

12.2 All repair welds in T91 shall be made with one of the following welding processes and consumables: SMAW, A5.5/A5.5M E90XX-B9; SAW, A5.23/A5.23M EB9 + neutral flux; GTAW, A5.28/A5.28M ER90S-B9; and FCAW A5.29/A5.29M E91T1-B9. In addition, the sum of the Ni+Mn content of all welding consumables used to weld repair T91 Types 1 and 2 shall not exceed 1.0 %.

12.3 All repair welds in T92, T93, T911, and T122, shall be made using welding consumables meeting the chemical requirements for the grade in [Table 1](#).

## 13. Permissible Variations from the Specified Wall Thickness

13.1 Permissible variations from the specified minimum wall thickness shall be in accordance with Specification [A1016/A1016M](#).

13.2 Permissible variations from the specified average wall thickness shall be  $\pm 10$  % of the specified average wall thickness for cold formed tubes and, unless otherwise specified by the purchaser, shall be in accordance with [Table 6](#) for hot formed tubes.

## 14. Surface Condition

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

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

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

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

## 15. Sampling

15.1 For flattening, flaring, and grain size requirements, the term lot applies to all tubes, prior to cutting, of the same size (see [4.1.7](#)) that are produced from the same heat of steel. When

**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, % <sup>B,C</sup> | Hardness <sup>A</sup>            |                  |
|-------------------------------------|-----------------|----------------------------------|--------------------------------|---|----------------------------------|------------------|
|                                     |                 |                                  |                                |   | Brinell/Vickers                  | Rockwell         |
| <i>Low Alloy Steels:</i>            |                 |                                  |                                |   |                                  |                  |
| T5b                                 | K51545          | 60 [415]                         | 30 [205]                       | 30  | 179 HBW/<br>190HV                | 89 HRB           |
| T9                                  | K90941          | 60 [415]                         | 30 [205]                       | 30  | 179 HBW/<br>190HV                | 89 HRB           |
| T12                                 | K11562          | 60 [415]                         | 32 [220]                       | 30  | 163 HBW/<br>170 HV               | 85 HRB           |
| T23                                 | K40712          | 74 [510]                         | 58 [400]                       | 20  | 220 HBW/<br>230 HV               | 97 HRB           |
| T24                                 | K30736          | 85 [585]                         | 60 [415]                       | 20  | 250 HBW/<br>265 HV               | 25 HRC           |
| T36 Class 1                         | K21001          | 90 [620]                         | 64 [440]                       | 15  | 250 HBW/<br>265 HV               | 25 HRC           |
| T36 Class 2                         | K21001          | 95.5 [660]                       | 66.5 [460]                     | 15  | 250 HBW/<br>265 HV               | 25 HRC           |
| T91 Types 1 and 2                   | K90901          | 85 [585]                         | 60 [415]                       | 20  | 190 to 250 HBW/<br>196 to 265 HV | 90 HRB to 25 HRC |
| T92                                 | K92460          | 90 [620]                         | 64 [440]                       | 20  | 250 HBW/<br>265 HV               | 25 HRC           |
| T93                                 | K91350          | 90 [620]                         | 64 [440]                       | 19  | 250 HBW/<br>265 HV               | 25 HRC           |
| T115                                | K91060          | 90 [620]                         | 65 [450]                       | 20  | 190 to 250 HBW/<br>196 to 265 HV | 90 HRB to 25 HRC |
| T122                                | K91271          | 90 [620]                         | 58 [400]                       | 20  | 250 HBW/<br>265 HV               | 25 HRC           |
| T128                                | K91421          | 94 [650]                         | 71 [490]                       | 20  | 265HBW/280HV                     | 27HRC            |
| T911                                | K91061          | 90 [620]                         | 64 [440]                       | 20  | 250 HBW/<br>265 HV               | 25 HRC           |
| T921                                | K91201          | 109 [750]                        | 84 [580]                       | 20  | 276 HBW/<br>290 HV               | 26 HRC           |
| All other low alloy grades          |                 | 60 [415]                         | 30 [205]                       | 30  | 163 HBW/<br>170 HV               | 85 HRB           |
| <i>Austenitic Stainless Steels:</i> |                 |                                  |                                |   |                                  |                  |
| TP201                               | S20100          | 95 [655]                         | 38 [260]                       | 35  | 219 HBW/<br>230 HV               | 95 HRB           |
| TP202                               | S20200          | 90 [620]                         | 45 [310]                       | 35  | 219 HBW/<br>230 HV               | 95 HRB           |
| XM-19                               | S20910          | 100 [690]                        | 55 [380]                       | 35  | 250 HBW/<br>265 HV               | 25 HRC           |
| ...                                 | S21500          | 78 [540]                         | 33 [230]                       | 35  | 192 HBW/<br>200 HV               | 90 HRB           |
| ...                                 | S25700          | 78 [540]                         | 35 [240]                       | 50  | 217 HBW                          | 95 HRB           |
| TP304                               | S30400          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV               | 90 HRB           |
| TP304L                              | S30403          | 70 [485]                         | 25 [170]                       | 35  | 192 HBW/<br>200 HV               | 90 HRB           |
| TP304H                              | S30409          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV               | 90 HRB           |
| ...                                 | S30432          | 86 [590]                         | 34 [235]                       | 35  | 219 HBW/<br>230 HV               | 95 HRB           |
| ...                                 | S30434          | 73 [500]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV               | 90 HRB           |
| TP304N                              | S30451          | 80 [550]                         | 35 [240]                       | 35  | 192 HBW/<br>200 HV               | 90 HRB           |
| TP304LN                             | S30453          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV               | 90 HRB           |
| ...                                 | S30615          | 90 [620]                         | 40 [275]                       | 35  | 192 HBW/<br>200 HV               | 90 HRB           |
| ...                                 | S30815          | 87 [600]                         | 45 [310]                       | 40  | 217 HBW                          | 95 HRB           |
| TP309S                              | S30908          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV               | 90 HRB           |
| TP309H                              | S30909          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV               | 90 HRB           |
| TP309LMoN                           | S30925          | 93 [640]                         | 38 [260]                       | 30  | 256 HBW/270 HV                   | 100 HRB          |
| TP309Cb                             | S30940          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV               | 90 HRB           |
| TP309HCb                            | S30941          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>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, % <sup>B,C</sup> | Hardness <sup>A</sup> |          |
|----------------------|-----------------|----------------------------------|--------------------------------|---|-----------------------|----------|
|                      |                 |                                  |                                |   | Brinell/Vickers       | Rockwell |
| ...                  | S30942          | 86 [590]                         | 34 [235]                       | 35  | 219 HBW/<br>230 HV    | 95 HRB   |
| ...                  | S31002          | 73 [500]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP310S               | S31008          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP310H               | S31009          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP310MoCbN           | S31025          | 93 [640]                         | 39 [270]                       | 30  | 256 HBW/<br>270 HV    | 100 HRB  |
|                      | S31035          | 95 [655]                         | 45 [310]                       | 40  | 220 HBW/<br>230 HV    | 96 HRB   |
| TP310Cb              | S31040          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP310HCb             | S31041          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP310HCbN            | S31042          | 95 [655]                         | 43 [295]                       | 30  | 256 HBW               | 100 HRB  |
| ...                  | S31043          | 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/<br>230 HV    | 96 HRB   |
| T > 0.187 in. [5 mm] |                 | 95 [655]                         | 45 [310]                       | 35  | 220 HBW/<br>230 HV    | 96 HRB   |
| ...                  | S31266          | 109 [750]                        | 61 [420]                       | 35  | ...                   | B100     |
| ...                  | 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/<br>200 HV    | 90 HRB   |
| TP316L               | S31603          | 70 [485]                         | 25 [170]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP316H               | S31609          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP316Ti              | S31635          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP316N               | S31651          | 80 [550]                         | 35 [240]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP317                | S31700          | 75 [515]                         | 30 [205]                       | 34  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP317L               | S31703          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| ...                  | S31725          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| ...                  | S31730          | 70 [480]                         | 25 [175]                       | 35  | ...                   | 90 HRB   |
| ...                  | S31740          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| ...                  | S32050          | 98 [675]                         | 48 [330]                       | 40  | 256 HBW               | 100 HRB  |
| TP321                | S32100          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP321H               | S32109          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| ...                  | S32615          | 80 [550]                         | 32 [220]                       | 25  | 192 HBW/<br>200 HV    | 90 HRB   |
| ...                  | S32716          | 80 [550]                         | 35 [240]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| ...                  | S33228          | 73 [500]                         | 27 [185]                       | 30  | 192 HBW/<br>200 HV    | 90 HRB   |
| ...                  | S34565          | 115 [790]                        | 60 [415]                       | 35  | 241 HBW               | 100 HRB  |
| TP347                | S34700          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP347W               | S34705          | 90 [620]                         | 38 [260]                       | 30  | 219 HBW/<br>230 HV    | 95 HRB   |
| TP347H               | S34709          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP347HFG             | S34710          | 80 [550]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP347LN              | S34751          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>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, % <sup>B,C</sup> | Hardness <sup>A</sup> |          |
|----------------------------------|-----------------|----------------------------------|--------------------------------|---|-----------------------|----------|
|                                  |                 |                                  |                                |   | Brinell/Vickers       | Rockwell |
| ...                              | S34752          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP348                            | S34800          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| TP348H                           | S34809          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| ...                              | S35045          | 70 [485]                         | 25 [170]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| XM-15                            | S38100          | 75 [515]                         | 30 [205]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| ...                              | S38815          | 78 [540]                         | 37 [255]                       | 30  | 256 HBW               | 100 HRB  |
| Alloy 20                         | N08020          | 80 [550]                         | 35 [240]                       | 30  | 217 HBW               | 95 HRB   |
|                                  | N08028          | 73 [500]                         | 31 [214]                       | 40  | ...                   | ...      |
|                                  | N08029          | 73 [500]                         | 31 [214]                       | 40  | ...                   | ...      |
|                                  | N08367          | ...                              | ...                            | ...   | ...                   | ...      |
| ...                              | ≤3/16 in. wall  | 100 [690]                        | 45 [310]                       | 30  | ...                   | 100 HRB  |
| ...                              | >3/16 in. wall  | 95 [655]                         | 45 [310]                       | 30  | 241 HBW               | ...      |
| 800                              | N08800          | ...                              | ...                            | ...   | ...                   | ...      |
| ...                              | cold-worked     | 75 [515]                         | 30 [205]                       | 30  | 192 HBW/<br>200 HV    | 90 HRB   |
| ...                              | annealed        | ...                              | ...                            | ...   | ...                   | ...      |
| ...                              | hot-finished    | 65 [450]                         | 25 [170]                       | 30  | 192 HBW/<br>200 HV    | 90 HRB   |
| ...                              | annealed        | ...                              | ...                            | ...   | ...                   | ...      |
| 800H                             | N08810          | 65 [450]                         | 25 [170]                       | 30  | 192 HBW/<br>200 HV    | 90 HRB   |
| ...                              | N08811          | 65 [450]                         | 25 [170]                       | 30  | 192 HBW/<br>200 HV    | 90 HRB   |
| ...                              | N08904          | 71 [490]                         | 31 [215]                       | 35  | 192 HBW/<br>200 HV    | 90 HRB   |
| ...                              | N08925          | 87 [600]                         | 43 [295]                       | 40  | 217 HBW               | 95 HRB   |
| ...                              | N08926          | 94 [650]                         | 43 [295]                       | 35  | 256 HBW               | 100 HRB  |
| <b>Ferritic Stainless Steels</b> |                 |                                  |                                |   |                       |          |
| TP444                            | S44400          | 60[415]                          | 40[275]                        | 20  | 217 HBW/ 230 HV       | 96 HRB   |

<sup>A</sup>Max, unless a range or a minimum is specified.

<sup>B</sup> When standard round 2 in. or 50 mm gauge length or smaller proportionally sized specimens with gauge 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, T93, T115, T122, T128, and T911; and except for TP444.

<sup>C</sup> For longitudinal strip tests, a deduction from the basic minimum elongation values of 1.00 % for TP444, T23, T24, T91, T92, T93, T115, T122, T128, and T911, and of 1.50 % for all other low alloy 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<sup>A</sup>*

| Wall Thickness       |            | Elongation in 2 in. or 50 mm, min, %                                       |     |      |                           |
|----------------------|------------|--|-----|------|---------------------------|
| in.                  | mm         | S44400, T23, T24, T91 Types 1 and 2, T92, T921, T115, T122, T128, and T911 | T93 | T 36 | All Other Ferritic Grades |
| 5/16 [0.312]         | 8          | 20   | 19  | 15   | 30                        |
| 3/32 [0.281]         | 7.2        | 19   | 18  | 14   | 29                        |
| 1/4 [0.250]          | 6.4        | 18   | 17  | 13   | 27                        |
| 7/32 [0.219]         | 5.6        | 17   | 16  | 12   | 26                        |
| 3/16 [0.188]         | 4.8        | 16   | 15  | 11   | 24                        |
| 5/32 [0.156]         | 4          | 15   | 14  | 10   | 23                        |
| 1/8 [0.125]          | 3.2        | 14   | 13  | 9    | 21                        |
| 3/32 [0.094]         | 2.4        | 13   | 12  | 8    | 20                        |
| 1/16 [0.062]         | 1.6        | 12   | 11  | 7    | 18                        |
| 0.062 to 0.035, excl | 1.6 to 0.9 | 12   | 11  | 7    | 17                        |
| 0.035 to 0.022, excl | 0.9 to 0.6 | 11   | 10  | 6    | 17                        |
| 0.022 to 0.015 incl  | 0.6 to 0.4 | 11   | 10  | 6    | 16                        |

<sup>A</sup> Calculated elongation requirements shall be rounded to the nearest whole number.

final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same

**TABLE 6 Permitted Variations in Average Wall Thickness for Hot Formed Tubes**

| NPS [DN] Designator                                      | Tolerance in %, from specified |       |
|--|--------------------------------|-------|
|  | Over                           | Under |
| 1/8 to 2 1/2 [6 to 65] incl, all t/D ratios <sup>A</sup> | 20                             | 12.5  |
| Above 2 1/2 [65], t/D ≤ 5 % <sup>A</sup>                 | 22.5                           | 12.5  |
| Above 2 1/2 [65], t/D > 5 % <sup>A</sup>                 | 15                             | 12.5  |

<sup>A</sup> t = specified wall thickness D = specified outside diameter

**TABLE 7 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 |

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 7](#).

15.2 For tensile and hardness test requirements, the term lot applies to all tubes prior to cutting, of the same size (see [4.1.7](#)) 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](#).

## 16. Product Marking

16.1 In addition to the marking prescribed in Specification [A1016/A1016M](#), the marking shall include: the condition, hot finished or cold finished; and the wall designation, minimum wall or average wall.

16.2 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.

16.3 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.

16.4 For T91, the marking shall also include the type.

## 17. Keywords

17.1 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 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 **A262**, 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 (A213/A213M – 21b) that may impact the use of this standard. (Approved May 1, 2022.)

- (1) Revised carbon maximum for UNS S31002 in **Table 2**.
- (2) Revised nitrogen from 0.18–0.22 to 0.18–0.25 for UNS S31254 in **Table 2**.

Committee A01 has identified the location of selected changes to this standard since the last issue (A213/A213M – 21a) that may impact the use of this standard. (Approved Nov. 1, 2021.)

- (1) Added Grade T128 (UNS designation K91421) to **Table 1**, **Table 3**, **Table 4**, **Table 5**, and **9.1.2**.

Committee A01 has identified the location of selected changes to this standard since the last issue (A213/A213M – 21) that may impact the use of this standard. (Approved May 1, 2021.)

- (1) Added UNS designation S31740 to **Table 2**, **Table 3**, and **Table 4**.

Committee A01 has identified the location of selected changes to this standard since the last issue (A213/A213M – 19a) that may impact the use of this standard. (Approved April 15, 2021.)

- (1) Added Grade T921 (UNS designation K91201) to **Table 1**, **Table 3**, **Table 4**, **Table 5**, and **9.1.2**.

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