

## ASTM A213 / A213M

Seamless Ferritic & Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes

Boiler Tubes

Superheater Tubes

Heat Exchanger Tubes

ID 1/8" – OD 5"

Wall 0.015" – 0.500"

### 1 Scope & Application

ASTM A213 covers seamless ferritic and austenitic alloy-steel tubes for high-temperature, high-pressure service in boilers, superheaters, and heat exchangers.

#### Product Form

Seamless cold-finished or hot-finished tubes only. No welded product is covered by this specification.

#### Size Range

Inside diameter 1/8" [3.2 mm] to 5" [127 mm]  
OD. Wall thickness 0.015" to 0.500" [0.4–12.7 mm].

#### Two Steel Families

**Ferritic Alloy Steels:** T2, T5, T9, T11, T12, T22, T91, T92, etc. — Cr-Mo creep-resistant grades.

**Austenitic Stainless:** TP304, TP316, TP321, TP347, etc. — corrosion and oxidation resistant.

#### "H" Grade Designation

Grades with "H" (e.g., TP304H, TP321H, TP347H) have higher carbon and/or controlled grain size for enhanced creep-rupture strength at elevated temperatures.

#### Key Applications

Power generation boilers, superheaters, reheaters, feedwater heaters, petrochemical furnace tubes, refinery heat exchangers, and nuclear steam generators.

#### ASME Code Accepted

Accepted under ASME Boiler & Pressure Vessel Code, Section II (as SA-213). Widely used in pressure-boundary applications.

## 2 Ferritic Alloy Steel Grades (T-Series)

Chromium-molybdenum (Cr-Mo) creep-resistant steels for high-temperature boiler and superheater tubing. These grades offer excellent strength at elevated temperatures up to 1200°F [650°C].

### T11

CR-MO

UNS K11597 • 1.25Cr-0.5Mo

Tensile 60 ksi

Yield 30 ksi

Elong 30%

The most widely used Cr-Mo boiler tube grade. Excellent balance of creep strength, weldability, and oxidation resistance. Service up to 1050°F [565°C].

### T22

CR-MO

UNS K21590 • 2.25Cr-1Mo

Tensile 60 ksi

Yield 30 ksi

Elong 30%

Higher chromium content than T11 for improved oxidation and corrosion resistance. Standard grade for superheater and reheater tubing up to 1100°F [595°C].

### T91

ADVANCED

UNS K90901 • 9Cr-1Mo-V-Nb

Tensile 85 ksi

Yield 60 ksi

Elong 20%

High-strength 9%Cr modified steel with V, Nb, and N microalloying. Significantly higher creep strength than T22. Used in ultra-supercritical boilers up to 1200°F [650°C].

### T92

ADVANCED

UNS K92460 • 9Cr-0.5Mo-1.8W-V-Nb

Tensile 90 ksi

Yield 64 ksi

Elong 20%

Tungsten-strengthened variant of T91. Up to 30% higher creep strength. Used in the hottest sections of advanced ultra-supercritical power plants.

### T5 / T5b / T5c

CR-MO

K41545 / K51545 • 5Cr-0.5Mo

Tensile 60 ksi

Yield 30 ksi

High Temp

5% chromium grades for enhanced oxidation and sulfidation resistance. Used in refinery heaters and petrochemical furnace tubes. T5b adds 1–2% Si for improved scaling resistance.

**CR-MO**

## T9

UNS K90941 • 9Cr-1Mo

Tensile 60 ksi

Yield 30 ksi

Elong 30%

9% chromium for superior high-temperature oxidation resistance. Traditional choice before T91 became the preferred advanced 9Cr grade.

**ADVANCED**

## T23 / T24

K40712 / K30736

T23: 2.25Cr-1.6W

T24: 2.25Cr-1Mo-V-Ti

Tensile 74–85 ksi

Low-carbon, boron-treated Cr-Mo grades with improved weldability (no PWHT required for thin sections). T23 uses W-strengthening; T24 uses V-Ti-B microalloying.

**CR-MO**

## T2 / T12

K11547 / K11562

T2: 0.5Cr-0.5Mo

T12: 1Cr-0.5Mo

Tensile 60 ksi

Lower-alloy Cr-Mo grades for moderate-temperature service. T12 bridges the gap between carbon steel and T11. Good formability and weldability.

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## Austenitic Stainless Steel Grades (TP-Series)

Corrosion and oxidation resistant austenitic stainless steel tubes for heat exchangers, superheaters, and corrosive high-temperature environments.

### TP304 / TP304L

MOST POPULAR

UNS S30400 / S30403

18Cr-8Ni

Tensile 75/70 ksi

Yield 30/25 ksi

General-purpose austenitic for heat exchanger tubing in moderate corrosive service. TP304L eliminates sensitization risk during welding. Max service ~1500°F [815°C].

### TP304H

HIGH TEMP

UNS S30409

C 0.04–0.10

Grain size  $\geq 7$ 

Tensile 75 ksi

High-carbon 304 with controlled coarse grain for superior creep-rupture strength in superheater and reheater tubing. Standard grade for fossil-fuel boiler service.

### TP316 / TP316L

MOST POPULAR

UNS S31600 / S31603

16Cr-10Ni-2Mo

Tensile 75/70 ksi

Pitting Resistant

Molybdenum-bearing grade for improved pitting and crevice corrosion resistance. TP316L is preferred for all-welded construction. Common in chemical plant and marine heat exchangers.

### TP321 / TP321H

STABILIZED

UNS S32100 / S32109

Ti-Stabilized

No Sensitization

Tensile 75 ksi

Titanium-stabilized for immunity to intergranular corrosion after welding or elevated-temperature exposure. TP321H adds grain size control for boiler superheater applications.

### TP347 / TP347H

STABILIZED

UNS S34700 / S34709

Nb-Stabilized

Superior Creep

Tensile 75 ksi

Niobium-stabilized with excellent high-temperature strength. TP347H is the preferred austenitic grade for superheater tubes in ultra-supercritical boilers. TP347HFG offers fine-grain variant.

## TP310S / TP310HCbN

HIGH TEMP

UNS S31008 / S31042

25Cr-20Ni

Oxidation 2000°F+

Tensile 75–95 ksi

High Cr-Ni for extreme oxidation resistance. TP310HCbN (HR3C) is a modern Nb/N-strengthened variant for ultra-supercritical boiler applications with outstanding steam oxidation resistance.

## S31254 / N08367

SUPER AUSTENITIC

UNS S31254 / N08367

6%Mo Super Austenitic

PREN ≥43

Tensile 95–100 ksi

High-molybdenum grades for aggressive chloride and acid environments. Superior to TP316 in seawater and chemical processing. Used where duplex stainless is insufficient.

## Alloy 800 / 800H

NI-ALLOY

N08800 / N08810

32Ni-21Cr

Tensile 65–75 ksi

Stress Corrosion Resistant

Nickel-iron-chromium alloy with excellent resistance to chloride stress-corrosion cracking. 800H adds controlled carbon and grain size for high-temperature creep strength.

# Chemical Composition

Key alloying elements for the most commonly ordered grades. Values in weight percent, maximum unless a range is given.

## FERRITIC ALLOY STEELS

| Grade | UNS    | C         | Mn        | Si        | Cr         | Mo        | Other                                     |
|-------|--------|-----------|-----------|-----------|------------|-----------|-------------------------------------------|
| T11   | K11597 | 0.05–0.15 | 0.30–0.60 | 0.50–1.00 | 1.00–1.50  | 0.44–0.65 | —                                         |
| T12   | K11562 | 0.05–0.15 | 0.30–0.61 | 0.50      | 0.80–1.25  | 0.44–0.65 | —                                         |
| T22   | K21590 | 0.05–0.15 | 0.30–0.60 | 0.50      | 1.90–2.60  | 0.87–1.13 | —                                         |
| T5    | K41545 | 0.15      | 0.30–0.60 | 0.50      | 4.00–6.00  | 0.45–0.65 | —                                         |
| T5b   | K51545 | 0.15      | 0.30–0.60 | 1.00–2.00 | 4.00–6.00  | 0.45–0.65 | —                                         |
| T9    | K90941 | 0.15      | 0.30–0.60 | 0.25–1.00 | 8.00–10.00 | 0.90–1.10 | —                                         |
| T91   | K90901 | 0.07–0.14 | 0.30–0.60 | 0.20–0.50 | 8.00–9.50  | 0.85–1.05 | V 0.18–0.25, Nb 0.06–0.10, N 0.03–0.07    |
| T92   | K92460 | 0.07–0.13 | 0.30–0.60 | 0.50      | 8.50–9.50  | 0.30–0.60 | W 1.50–2.00, V 0.15–0.25, Nb 0.04–0.09    |
| T23   | K40712 | 0.04–0.10 | 0.10–0.60 | 0.50      | 1.90–2.60  | 0.05–0.30 | W 1.45–1.75, V 0.20–0.30, B 0.001–0.006   |
| T24   | K30736 | 0.05–0.10 | 0.30–0.70 | 0.15–0.45 | 2.20–2.60  | 0.90–1.10 | V 0.20–0.30, Ti 0.06–0.10, B 0.0015–0.007 |

## AUSTENITIC STAINLESS STEELS

| Grade  | UNS    | C max     | Cr        | Ni       | Mo | Others |
|--------|--------|-----------|-----------|----------|----|--------|
| TP304  | S30400 | 0.08      | 18.0–20.0 | 8.0–11.0 | —  | —      |
| TP304L | S30403 | 0.035     | 18.0–20.0 | 8.0–12.0 | —  | —      |
| TP304H | S30409 | 0.04–0.10 | 18.0–20.0 | 8.0–11.0 | —  | —      |

| Grade  | UNS    | C max     | Cr        | Ni        | Mo        | Others                    |
|--------|--------|-----------|-----------|-----------|-----------|---------------------------|
| TP316  | S31600 | 0.08      | 16.0–18.0 | 10.0–14.0 | 2.00–3.00 | —                         |
| TP316L | S31603 | 0.035     | 16.0–18.0 | 10.0–14.0 | 2.00–3.00 | —                         |
| TP316H | S31609 | 0.04–0.10 | 16.0–18.0 | 10.0–14.0 | 2.00–3.00 | —                         |
| TP321  | S32100 | 0.08      | 17.0–19.0 | 9.0–12.0  | —         | Ti 5×C–0.70               |
| TP321H | S32109 | 0.04–0.10 | 17.0–19.0 | 9.0–12.0  | —         | Ti 4×C–0.70               |
| TP347  | S34700 | 0.08      | 17.0–19.0 | 9.0–13.0  | —         | Cb+Ta 10×C–1.00           |
| TP347H | S34709 | 0.04–0.10 | 17.0–19.0 | 9.0–13.0  | —         | Cb+Ta 8×C–1.00            |
| S31254 | S31254 | 0.020     | 19.5–20.5 | 17.5–18.5 | 6.0–6.5   | N 0.18–0.22, Cu 0.50–1.00 |
| N08367 | N08367 | 0.030     | 20.0–22.0 | 23.5–25.5 | 6.0–7.0   | N 0.18–0.25, Cu 0.75      |
| TP310S | S31008 | 0.08      | 24.0–26.0 | 19.0–22.0 | —         | —                         |
| 800H   | N08810 | 0.05–0.10 | 19.0–23.0 | 30.0–35.0 | —         | Fe ≥39.5, Al+Ti 0.30–1.20 |

P max 0.025% (ferritic) / 0.045% (austenitic); S max 0.025% (ferritic) / 0.030% (austenitic); Si 0.75% max (austenitic). Mn 2.00% max (austenitic).

# Mechanical Properties

Room-temperature tensile and hardness requirements. Elongation values are for standard 2 in. [50 mm] gauge length specimens; see Table 5 for thin-wall deductions.

| Grade                       | UNS             | Tensile<br>ksi [MPa] | Yield<br>ksi [MPa] | Elong.<br>% | Hardness max<br>HBW / HRB |
|-----------------------------|-----------------|----------------------|--------------------|-------------|---------------------------|
| Ferritic Alloy Steels       |                 |                      |                    |             |                           |
| T11 / T22                   | K11597 / K21590 | 60 [415]             | 30 [205]           | 30          | 163 / 85                  |
| T5 / T9 / T2 / T12          | —               | 60 [415]             | 30–32 [205–220]    | 30          | 163–179 / 85–89           |
| T91                         | K90901          | 85 [585]             | 60 [415]           | 20          | 190–250 / 90–25HRC        |
| T92                         | K92460          | 90 [620]             | 64 [440]           | 20          | 250 / 25HRC               |
| T23                         | K40712          | 74 [510]             | 58 [400]           | 20          | 220 / 97                  |
| T24                         | K30736          | 85 [585]             | 60 [415]           | 20          | 250 / 25HRC               |
| T122                        | K91271          | 90 [620]             | 58 [400]           | 20          | 250 / 25HRC               |
| Austenitic Stainless Steels |                 |                      |                    |             |                           |
| TP304 / TP304H              | S30400 / S30409 | 75 [515]             | 30 [205]           | 35          | 192 / 90                  |
| TP304L                      | S30403          | 70 [485]             | 25 [170]           | 35          | 192 / 90                  |
| TP316 / TP316H              | S31600 / S31609 | 75 [515]             | 30 [205]           | 35          | 192 / 90                  |
| TP316L                      | S31603          | 70 [485]             | 25 [170]           | 35          | 192 / 90                  |
| TP321 / TP321H              | S32100 / S32109 | 75 [515]             | 30 [205]           | 35          | 192 / 90                  |
| TP347 / TP347H              | S34700 / S34709 | 75 [515]             | 30 [205]           | 35          | 192 / 90                  |
| TP347HFG                    | S34710          | 80 [550]             | 30 [205]           | 35          | 192 / 90                  |
| TP310S / TP310H             | S31008 / S31009 | 75 [515]             | 30 [205]           | 35          | 192 / 90                  |
| TP310HCbN                   | S31042          | 95 [655]             | 43 [295]           | 30          | 256 / 100                 |
| S31254                      | S31254          | 95–98 [655–675]      | 45 [310]           | 35          | 220 / 96                  |
| N08367                      | N08367          | 95–100 [655–690]     | 45 [310]           | 30          | 241 / 100                 |
| 800H                        | N08810          | 65 [450]             | 25 [170]           | 30          | 192 / 90                  |
| TP444 (Ferritic SS)         | S44400          | 60 [415]             | 40 [275]           | 20          | 217 / 96                  |

### **Elongation Notes for Thin-Wall Tubes**

- ✓ For standard round specimens (2" or 50 mm gauge, or 4D): minimum elongation 22% for low-alloy grades except T23/T24/T91/T92/T122/T911
- ✓ For longitudinal strip tests: deduct 1.00% (T23/T24/T91/T92/T122/T911/TP444) or 1.50% (other low-alloy) per 1/32" [0.8 mm] wall decrease below 5/16" [8 mm]
- ✓ Unstraightened tubes (Supplementary S3): reduce minimum yield by 5 ksi [35 MPa]

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# Heat Treatment

Heat treatment is critical for achieving the required microstructure and properties. Ferritic grades use normalize-and-temper; austenitic grades use solution annealing.

## FERRITIC ALLOY STEELS

| Grade          | Heat Treatment                    | Normalizing Temp °F [°C] | Tempering Temp °F [°C] |
|----------------|-----------------------------------|--------------------------|------------------------|
| T11, T22       | Normalize & Temper or Full Anneal | N/A (full anneal)        | 1200–1250 [650–675]    |
| T5, T9         | Normalize & Temper or Full Anneal | N/A                      | 1250 [675]             |
| T91, T92, T122 | Normalize & Temper                | 1900–1975 [1040–1080]    | 1350–1470 [730–800]    |
| T23            | Normalize & Temper                | 1900–1975 [1040–1080]    | 1350–1470 [730–800]    |
| T24            | Normalize & Temper                | 1800–1870 [980–1020]     | 1350–1420 [730–770]    |
| T911           | Normalize & Temper                | 1900–1975 [1040–1080]    | 1365–1435 [740–780]    |

## AUSTENITIC STAINLESS STEELS

| Grade(s)                                                     | Solution Temperature °F [°C]                                    | Cooling                    | Grain Size Req. |
|--------------------------------------------------------------|-----------------------------------------------------------------|----------------------------|-----------------|
| TP304, TP304L, TP316, TP316L<br>TP321, TP347, TP309S, TP310S | 1900 [1040] min                                                 | Water quench or rapid cool | None            |
| TP304H, TP316H                                               | 1900 [1040] min                                                 | Water quench or rapid cool | 7 or coarser    |
| TP321H, TP347H, TP348H<br>Cold-worked                        | 2000 [1090–1100] min                                            | Water quench or rapid cool | 7 or coarser    |
| TP321H, TP347H, TP348H<br>Hot-rolled                         | 1925 [1050] min                                                 | Water quench or rapid cool | 7 or coarser    |
| TP347HFG                                                     | 2150 [1175] min (after softening treatment ≥90°F [50°C] higher) | Water quench or rapid cool | 7–10            |
| TP310HCbN (S31042)                                           | 1900 [1040] min                                                 | Water quench or rapid cool | 7 or coarser    |

| Grade(s)            | Solution Temperature °F [°C]  | Cooling                    | Grain Size Req. |
|---------------------|-------------------------------|----------------------------|-----------------|
| S31254, N08367      | 2100 / 2025 [1150 / 1105] min | Water quench or rapid cool | None            |
| Alloy 800H (N08810) | 2050 [1120] min               | Water quench or rapid cool | 5 or coarser    |

Heat Treatment Notes

- ✓ All austenitic grades must be quenched rapidly enough to prevent carbide re-precipitation
- ✓ Solution temperatures above 1950°F [1065°C] may impair intergranular corrosion resistance in stabilized grades — lower-temperature stabilization anneal may be specified (Supplementary S2)
- ✓ "H" grades require grain size control to ensure adequate creep-rupture strength at elevated temperatures
- ✓ Ferritic grades may be supplied in full annealed, isothermal annealed, or normalized-and-tempered condition

## 7 Testing & Inspection

Mandatory and optional tests to verify conformance. All testing governed by ASTM A1016/A1016M unless otherwise specified.

| Test                     | Frequency                      | Key Details                                                                                                                                                |
|--------------------------|--------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Hydrostatic / NDE</b> | Each tube                      | Hydrostatic test or nondestructive electric test (eddy current / ultrasonic). Manufacturer's option unless specified in order.                             |
| <b>Tensile Test</b>      | 1 per lot                      | Lot = same size tubes from same heat. For batch furnace: same furnace charge. For continuous furnace/quench: per Table 7 (50–125 tubes depending on size). |
| <b>Hardness Test</b>     | 1 per lot                      | Brinell, Vickers, or Rockwell. Per Table 4 requirements. Required for all grades.                                                                          |
| <b>Flattening Test</b>   | Per lot (same size, same heat) | Crop ends may be used. Tubes must flatten without cracking to specified plate distance.                                                                    |
| <b>Flaring Test</b>      | Per lot                        | Tube end expanded with 60° cone. No cracking permitted at specified expansion percentage.                                                                  |
| <b>Grain Size</b>        | Per lot (same as flattening)   | Required for all "H" grade austenitic tubes (per Table 3). ASTM E112 methods.                                                                              |
| <b>Surface Condition</b> | Each tube                      | Ferritic cold-finished: free of scale. Ferritic hot-finished: free of loose scale. Stainless: pickled free of scale (bright anneal exempt).                |

### Optional Supplementary Requirements

- ✓ **S1:** Stress-Relieved Annealed Tubes — for TP304L, TP316L, TP321, TP347, TP348 in chloride stress-corrosion service. Heat at 1500–1650°F [815–900°C] after straightening.
- ✓ **S2:** Stabilizing Heat Treatment — additional lower-temperature stabilization for Ti/Nb grades after solution annealing.
- ✓ **S3:** Unstraightened Tubes — coils or U-bend stock supplied in as-heat-treated condition. Reduced yield (minus 5 ksi). Marked with "U" suffix (e.g., 304-U).
- ✓ **S4:** Intergranular Corrosion Test — ASTM A262 Practice E. Sensitized condition for L/stabilized grades; as-shipped for others.

## Ordering Information

Essential information to include when placing an order. Clear specifications ensure correct product delivery.

### Required Information

- ✓ **Quantity:** Feet, metres, or number of lengths
- ✓ **Name of Material:** Seamless tubes
- ✓ **Grade:** Per Table 1 (ferritic) or Table 2 (austenitic)
- ✓ **Condition:** Hot-finished or cold-finished
- ✓ **Size:** Outside diameter and minimum wall thickness (or average wall, if specified)
- ✓ **Length:** Specific cut lengths or random
- ✓ **Test Type:** Hydrostatic test or Nondestructive Electric Test (see 10.1)
- ✓ **Specification:** ASTM A213 (inch-pound) or A213M (metric), including year of issue

### Optional Requirements (Specify If Needed)

- ✓ Supplementary requirements S1 through S4
- ✓ Average wall thickness instead of minimum wall
- ✓ Controlled structural characteristics (see 6.3)
- ✓ Special finish requirements
- ✓ Certification and test report details
- ✓ Level of preservation and packing
- ✓ Intergranular corrosion testing (S4)

### Example Order Descriptions

**Ferritic:** ASTM A213 – Seamless Tubes – Grade T22 – Cold-Finished – 2.000" OD × 0.200" Min Wall × 40 ft Random – With MTR

**Austenitic:** ASTM A213/A213M – Seamless Tubes – Grade TP347H – Cold-Finished – 50.8 mm OD × 6.0 mm Min Wall × 12 m RL – ET Tested – With MTR

## Key Takeaways

### Two Steel Families

**Ferritic (T-series):** Cr-Mo steels for creep strength in boiler/superheater service. **Austenitic (TP-series):** Stainless steels for corrosion + high-temperature oxidation resistance.

### "H" = High-Temperature Optimized

Higher carbon (0.04–0.10%) + controlled coarse grain for enhanced creep-rupture strength. Critical for ASME code pressure-boundary applications at elevated temperatures.

### Advanced 9Cr Grades

T91 and T92 offer 30–60% higher allowable stress than T22 at boiler temperatures. The preferred choice for modern ultra-supercritical power plants.

### Marking Required

Each tube marked with: condition (hot/cold finished), wall designation (min/avg), heat number, heat-treatment lot ID (for austenitic H-grades), and "S" suffix for higher-sulfur T2/T12.

### Important Disclaimer

This guide is a condensed summary for customer reference only. It does not replace the full ASTM A213/A213M standard. Always refer to the latest official ASTM standard for complete requirements, detailed testing procedures, and regulatory compliance. For safety-critical boiler and pressure vessel applications, consult with qualified engineers.