

ASTM - A376/A376M

SPECIFICATION FOR SEAMLESS AUSTENITIC STEEL PIPE FOR HIGH-TEMPERATURE CENTRAL-STATION SERVICE

This specification covers seamless austenitic steel pipe intended for high-temperature central-station service. Among the grades covered are five H grades and two nitrogen grades (304N and 316N) that are specifically intended for high-temperature service.

A. Heat Treatment :-

1. Grades TP304, TP304N, TP304LN, TP316, TP316N, TP316LN, TP321, TP347, TP348, 16-8-2H, S31725, and S31726 :-
Unless otherwise stated in the order, heat treatment shall consist of heating to a minimum temperature of 1900°F [1040°C] and quenching in water or rapidly cooling by other means.
2. Grades TP304H, TP316H, TP321H, TP347H, TP348H, and 16-8-2H :-
If cold working is involved in processing, the minimum solution-treating temperature for Grades TP321H, TP347H, and TP348H shall be 2000°F [1100°C], for Grades TP304H and TP316H, 1900°F [1040°C], and for Grade 16-8-2H, 1800°F [980°C].
If the material is hot-rolled, the minimum solution-treating temperatures for Grades TP321H, TP347H, and TP348H shall be 1925°F [1050°C], for Grades TP304H and TP316H, 1900°F [1040°C], and for Grade 16-8-2H, 1800°F [980°C].
3. Grade S34565 :-
Heat treatment shall consist of heating to a temperature in the range of 2050°F [1120°C] minimum and 2140°F [1170°C] maximum, and quenching in water or rapidly cooling by other means.
4. A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP321, TP321H, TP347, TP347H, TP348, and TP348H. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal.

B. Grain Size :-

1. The grain size of grades 304H, 316H, 321H, 347H, and 348H as determined in accordance with Test Methods E 112, shall be No. 7 or coarser.

C. Chemical Composition :-

The steel shall conform to the requirements as to chemical composition prescribed in Table 1.

Table 1

Grade	UNS Designation	Carbon	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Nitrogen (A)	Others
TP304	S30400	0.08 max	2	0.045	0.03	0.75	8.0–11.0	18.0–20.0	...	...	...
TP304H	S30409	0.04–0.10	2	0.045	0.03	0.75	8.0–11.0	18.0–20.0	...	...	...
TP304N	S30451	0.08 max	2	0.045	0.03	0.75	8.0–11.0	18.0–20.0	...	0.10–0.16	...
TP304LN	S30453	0.035 max	2	0.045	0.03	0.75	8.0–11.0	18.0–20.0	...	0.10–0.16	...
TP316	S31600	0.08 max	2	0.045	0.03	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...
TP316H	S31609	0.04–0.10	2	0.045	0.03	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...
TP316N	S31651	0.08 max	2	0.045	0.03	0.75	11.0–14.0	16.0–18.0	2.00–3.00	0.10–0.16	...
TP316LN	S31653	0.035 max	2	0.045	0.03	0.75	11.0–14.0	16.0–18.0	2.00–3.00	0.10–0.16	...
TP321	S32100	0.08 max	2	0.045	0.03	0.75	9.0–13.0	17.0–19.0	...	...	(B)
TP321H	S32109	0.04–0.10	2	0.045	0.03	0.75	9.0–13.0	17.0–19.0	...	...	(C)
TP347	S34700	0.08 max	2	0.045	0.03	0.75	9.0–13.0	17.0–19.0	...	...	(D)
TP347H	S34709	0.04–0.10	2	0.045	0.03	0.75	9.0–13.0	17.0–19.0	...	...	(E)
TP348 (F)	S34800	0.08 max	2	0.045	0.03	0.75	9.0–13.0	17.0–19.0	...	...	Ta 0.1, Co 0.20 max, (D)
TP348H	S34809	0.04–0.10	2	0.045	0.03	1	9.0–13.0	17.0–19.0	...	...	(E)

16-8-2H	S16800	0.05–0.10	2	0.045	0.03	0.75	7.5–9.5	14.5–16.5	1.50–2.00	...	...
...	S31725	0.030 max	2	0.045	0.03	0.75	13.5–17.5	18.0–20.0	4.0–5.0	0.20 max	Cu 0.75 max
...	S31726	0.030 max	2	0.045	0.03	0.75	14.5–17.5	17.0–20.0	4.0–5.0	0.10–0.20	Cu 0.75 max
...	S34565	0.030 max	5.0–7.0	0.03	0.01	1	16.0–18.0	23.0–25.0	4.0–5.0	0.040–0.060	Cu 0.75 max

NOTES:

- (A) The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
 (B) The titanium content shall be not less than five times the carbon content and not more than 0.70%.
 (C) The titanium content shall be not less than four times the carbon content and not more than 0.70%.
 (D) The columbium content shall be not less than ten times the carbon content and not more than 1.10%.
 (E) The columbium content shall be not less than eight times the carbon content and not more than 1.10%. (F) This grade is intended for special purpose applications.

D. Tensile Requirements :-

The material shall conform to the requirements as to tensile properties prescribed in Table 2.

Table 2

Grade	Tensile (A) Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm (or 4D) min, %	
			Longitudinal	Transverse
TP304, TP304H, TP304LN, TP316,	75 [515]	30 [205]	35	25
TP304N, TP316N, S31726	80 [550]	35 [240]	35	25
S34565	115 [790]	60 [415]	35	30
TP321, TP321H :-				
≤3/8"	75 [515]	30 [205]	35	25
>3/8" (B)	70 [480]	25 [170]	35	25

NOTES:

- (A) For grade TP304, NPS 8 or larger, and in schedules 140 and heavier, the required minimum tensile strength shall be 70 ksi [480 MPa].
 (B) Prior to the issuance of A 376/A 376M — 88, the tensile and yield strength values were 75 [520] and 30 [210] respectively, for nominal wall greater than 3/8 in. [9.5 mm].

E. Hydrostatic or Non-destructive Electric Test :-

Each pipe shall be subjected to the Non-destructive Electric Test or the Hydrostatic Test. Unless specified by the purchaser, either test may be used at the option of the producer.

1. Hydrostatic Test :-

- i. Except as allowed by 'point E.1.ii and E.1.iii', each length of pipe shall be tested by the manufacturer to a hydrostatic pressure that will produce in the pipe wall a stress not less than 60 % of the specified minimum yield strength for ferritic alloy steel and stainless steel pipe, or 50 % of the specified minimum yield strength for austenitic alloy and stainless steel pipe and for ferritic/austenitic stainless steel pipe. The test pressure or stress shall be determined using the following equation:

$$P = 2St/D \text{ or } S = PD/2t \quad \dots\dots(3)$$

Where: P = hydrostatic test pressure in psi [MPa], S = pipe wall stress in psi or [MPa],

t = specified wall thickness, nominal wall thickness according to specified ANSI schedule number, or 1.143 times the specified minimum wall thickness, in. [mm], and

D = specified outside diameter, outside diameter corresponding to specified ANSI pipe size, or outside diameter calculated by adding 2t (as defined above) to the specified inside diameter, in. [mm].

The hydrostatic test pressure determined by Eq 3 shall be rounded to the nearest 50 psi [0.5 MPa] for pressures below 1000 psi [7 MPa], and to the nearest 100 psi [1 MPa] for pressures 1000 psi [7 MPa] and above.

- ii. Regardless of pipe-wall stress-level determined by Eq 3, the minimum hydrostatic test pressure required to satisfy these requirements need not exceed 2500 psi [17.0 MPa] for outside diameters (see D in point E.1.i) of 3.5 in. [88.9 mm] or less, or 2800 psi [19.0 MPa] for outside diameters over 3.5 in. [88.9 mm]. iii. With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements of point E.1.i or E.1.ii, or both, may be stated in the purchase order.
- iv. The test pressure shall be held for a minimum of 5 s. For welded pipe, the test pressure shall be held for a time sufficient to permit the entire length of the welded seam to be inspected.

2. Non-destructive Examination :-

i. The ultrasonic testing (UT) :-

- a. The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented defects. The examination may not detect short, deep, defects.
- b. For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.00 MHz and the maximum nominal transducer size shall be 1.5 in. ii. The eddy-current testing (ET) :-

- a. The eddy-current testing (ET) referenced in Practice E 426 has the capability of detecting significant discontinuities, especially the short abrupt type.
- b. For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide good signal-to-noise ratio.
- c. The maximum eddy-current coil frequency used shall be as follows:

On specified walls up to 0.050 in. — 100 KHz max
On specified walls up to 0.150 in. — 50 KHz max

On specified walls up to 0.150 in. — 10 KHz max

d. For Eddy-Current Testing, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

- Drilled Hole — The reference standard shall contain three or more holes, equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The hole diameter shall vary with NPS as follows:

<u>NPS Designator</u>	<u>Hole Diameter</u>
	0.039 in. (1 mm)
above 1/2 to 1.1/4	0.055 in. (1.4 mm)
above 1.1/4 to 2	0.071 in. (1.8 mm)
above 2 to 5	0.087 in. (2.2 mm)
above 5	0.106 in. (2.7 mm)

- Transverse Tangential Notch — Using a round tool or file with a 1/4 in. (6.4 mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding 12 1/2% of the specified nominal wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.
- Longitudinal Notch — A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12 1/2% of the specified wall thickness of the pipe or 0.004 in., whichever is greater. The length of the notch shall be compatible with the testing method.

F. Mechanical Tests Required :-

1. Transverse or Longitudinal Tension Test.
2. Flattening Test.

G. Supplementary Tests :- 1.

1. Transverse Tension Tests.
2. Flattening Test.
3. Etching Tests.
4. Ultrasonic Test.
5. Hot Ductility Test for Indicating Weldability.
6. Intergranular Corrosion Test.

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