



# Standard Specification for Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service<sup>1</sup>

This standard is issued under the fixed designation A376/A376M; 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.

## 1. Scope

1.1 This specification<sup>2</sup> 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.

1.2 Optional supplementary requirements (S1 through S10) are provided. These supplementary requirements specify additional tests that will be made only when stated in the order, together with the number of such tests required.

1.3 Grades TP321 and TP321H have lower strength requirements for nominal wall thicknesses greater than  $\frac{3}{8}$  in. [9.5 mm].

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system 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.

NOTE 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

## 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

A999/A999M Specification for General Requirements for

<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 Oct. 1, 2011. Published March 2012. Originally approved in 1954. Last previous edition approved in 2006 as A376/A376M–06. DOI: 10.1520/A0376\_A0376M-06R11.

<sup>2</sup> For ASME Boiler and Pressure Vessel Code applications see related Specification SA-376 in Section II of that Code.

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

### Alloy and Stainless Steel Pipe

E112 Test Methods for Determining Average Grain Size

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys

### 2.2 Other Standards:

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing<sup>4</sup>

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A941.

## 4. Ordering Information

4.1 Orders for material to this specification should include the following, as required to describe the desired material adequately:

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

4.1.2 Name of material (seamless austenitic steel pipe),

4.1.3 Grade (Table 1),

4.1.4 Size (nominal size, or outside diameter and schedule number or average wall thickness),

4.1.5 Lengths (specific or random), (Permissible Variations in Length Section of Specification A999/A999M),

4.1.6 End finish (Ends Section of Specification A999/A999M),

4.1.7 Optional requirements (Section 9) (see Hydrostatic Test Requirements Section and the Permissible Variation in Weight for Seamless Pipe Section for weighing individual lengths, of Specification A999/A999M), (see 10.6, repairing by welding; 14.3, die stamping),

4.1.8 Test report required (Certification Section of Specification A999/A999M),

4.1.9 Specification designation, and

4.1.10 Special requirements or any supplementary requirements selected, or both.

<sup>4</sup> Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518.

**TABLE 1 Chemical Requirements**

Grade	UNS Designation	Composition, %												
		Carbon	Man-ganese, max	Phos-phorus, max	Sul-fur, max	Sili-con, max	Nickel	Chromium	Molyb-denium	Tita-nium	Colum-bium	Tan-talum	Nitro-gen <sup>A</sup>	Others
TP304	S30400	0.08 max	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	...	...	...	...	...	...
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	...	...	...	...	...	...
TP304N	S30451	0.08 max	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...
TP304LN	S30453	0.035 max	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	...	...	...	...	0.10–0.16	...
TP316	S31600	0.08 max	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	...	...
TP316N	S31651	0.08 max	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	0.10–0.16	...
TP316LN	S31653	0.035 max	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	...	...	...	0.10–0.16	...
TP321	S32100	0.08 max	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	<i>B</i>	...	...	...	...
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	<i>C</i>	...	...	...	...
TP347	S34700	0.08 max	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	...	<i>D</i>	...	...	...
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	...	<i>E</i>	...	...	...
TP348 <sup>F</sup>	S34800	0.08 max	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	...	...	<i>D</i>	0.10	...	Co 0.20 max
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	9.0–13.0	17.0–19.0	...	...	<i>E</i>	0.10	...	...
16-8-2H	S16800	0.05–0.10	2.00	0.045	0.030	0.75	7.5–9.5	14.5–16.5	1.50–2.00	...	...	...	...	...
...	S31725	0.030 max	2.00	0.045	0.030	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	2.00	0.045	0.030	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	0.030	0.010	1.0	16.0–18.0	23.0–25.0	4.0–5.0	...	...	...	0.040–0.060	Cb 0.10 max

<sup>A</sup> The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

<sup>B</sup> The titanium content shall be not less than five times the carbon content and not more than 0.70 %.

<sup>C</sup> The titanium content shall be not less than four times the carbon content and not more than 0.70 %.

<sup>D</sup> The columbium content shall be not less than ten times the carbon content and not more than 1.10 %.

<sup>E</sup> The columbium content shall be not less than eight times the carbon content and not more than 1.10 %.

<sup>F</sup> This grade is intended for special purpose applications.

## 5. General Requirements

5.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification **A999/A999M** unless otherwise provided herein.

## 6. Materials and Manufacture

6.1 *Manufacture*—At the manufacturer’s option, pipe may be either hot finished or cold finished, with a suitable finishing treatment, where necessary.

### 6.2 Heat Treatment:

6.2.1 All pipe shall be furnished in the heat-treated condition unless the order specifically states that no final heat treatment shall be applied. When the order is furnished without final heat treatment, each pipe shall be stenciled “HT-O.”

6.2.2 As an alternate to final heat treatment in a continuous furnace or batch-type furnace, immediately following hot forming while the temperature of the pipes is not less than the specified minimum solution treatment temperature, pipes may be individually quenched in water or rapidly cooled by other means.

6.2.3 *Grades TP304, TP304N, TP304LN, TP316, TP316N, TP316LN, TP321, TP347, TP348, 16-8-2H, S 31725, and S 31726*—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.

6.2.3.1 The purchaser may specify controlled structural or special service characteristics which shall be used as a guide for the most suitable heat treatment. If the final heat treatment is at a temperature under 1900 °F [1040 °C], each pipe shall be stenciled with the final heat treatment temperature in degrees Fahrenheit or Celsius after the suffix “HT.”

6.2.4 *Grades TP304H, TP316H, TP321H, TP347H, TP348H, and 16-8-2H*—If cold working is involved in pro-

cessing, 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].

6.2.5 *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.

6.3 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 (see Supplementary Requirement S9).

6.4 The grain size of grades 304H, 316H, 321H, 347H, and 348H as determined in accordance with Test Methods **E112**, shall be No. 7 or coarser.

## 7. Chemical Composition

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

## 8. Product Analysis

8.1 At the request of the purchaser, an analysis of one billet from each heat or two pipes from each lot (**Note 2**) shall be made by the manufacturer. A lot of pipe shall consist of the following:

NPS Designator	Lengths of Pipe in Lot
Under NPS 2	400 or fraction thereof
NPS 2 to NPS 5, incl	200 or fraction thereof
Over NPS 5	100 or fraction thereof

NOTE 2—A lot shall consist of the number of lengths specified in 8.1 of the same size and wall thickness from any one heat of steel.

8.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Table 1.

8.3 If the analysis of one of the tests specified in Section 9 does not conform to the requirements specified in Section 7, an analysis of each billet or pipe from the same heat or lot may be made, and all billets or pipe conforming to the requirements shall be accepted.

## 9. Tensile Requirements

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

## 10. Workmanship, Finish, and Appearance

10.1 The pipe manufacturer shall explore a sufficient number of visual surface imperfections to provide reasonable assurance that they have been properly evaluated with respect to depth. Exploration of all surface imperfections is not required but may be necessary to assure compliance with 10.2.

10.2 Surface imperfections that penetrate more than 12½ % of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with such defects shall be given one of the following dispositions:

10.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

10.2.2 Repaired in accordance with the repair welding provisions of 10.6.

10.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

10.2.4 Rejected.

10.3 To provide a workmanlike finish and basis for evaluating conformance with 10.2, the pipe manufacturer shall remove by grinding the following:

10.3.1 Mechanical marks, abrasions (see Note 3), and pits, any of which imperfections are deeper than ¼ in. [1.6 mm].

NOTE 3—Marks and abrasions are defined as cable marks, dings, guide marks, roll marks, ball scratches, scores, die marks, and so forth.

10.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 10.1 to be deeper than 5 % of the nominal wall thickness.

10.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 10.2 are not scattered, but appear over a large area in excess of what is considered a workmanlike finish. Disposition of such pipe shall be a matter of agreement between the manufacturer and the purchaser.

10.5 When imperfections or defects are removed by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

10.5.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of dispute, the measurement determined by use of the mechanical caliper shall govern.

10.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A999/A999M.

10.7 The finished pipe shall be reasonably straight.

10.8 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser may request that a passivating treatment be applied.

**TABLE 2 Tensile Requirements**

Grade	Tensile <sup>A</sup> 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, TP316H, TP316LN, TP347, TP347H, TP348, TP348H, 16-8-2H, S31725	75 [515]	30 [205]	35	25
TP304N, TP316N, S31726	80 [550]	35 [240]	35	25
S34565	115 [790]	60 [415]	35	30
TP321, 321H				
≤¾ "	75 [515]	30 [205]	35	25
>¾ " <sup>B</sup>	70 [480]	25 [170]	35	25

<sup>A</sup>For grade TP304, NPS8 or larger, and in schedules 140 and heavier, the required minimum tensile strength shall be 70 ksi [480 MPa].

<sup>B</sup>Prior to the issuance of A376/A376M – 88, the tensile and yield strength values were 75 [520] and 30 [210] respectively, for nominal wall greater than ¾ in. [9.5 mm].

## 11. Hydrostatic or Nondestructive Electric Test

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

11.2 *Hydrostatic Test*— Each length of finished pipe shall be subjected to the hydrostatic test in accordance with Specification A999/A999M, unless specifically exempted under the provisions of 11.3 and 11.4.

11.3 For pipe sizes NPS 24 and over, the purchaser, with the agreement of the manufacturer, may complete the hydrostatic test requirement with the system pressure test, which may be lower or higher than the specification test pressure, but in no case shall the test pressure be lower than the system design pressure. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory marking the letters "NH."

11.4 *Nondestructive Examination*—Each pipe shall be examined with a nondestructive test in accordance with Practice E213 or Practice E426. Unless specifically called out by the purchaser, the selection of the nondestructive electric test will be at the option of the manufacturer. The range of pipe sizes