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Used in USDOE-NE standards

Standard Specification for Seamless Austenitic Steel Pipe for High-Temperature Service¹

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 reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

1. Scope*

1.1 This specification² covers seamless austenitic steel pipe intended for high-temperature service. Among the grades covered are H grades and nitrogen grades that are specifically intended for high-temperature service.

NOTE 1—This specification was originally developed for use for piping in the central stations of electric-power generating thermal plants. However, its use is not restricted to such applications and it may be used in other applications for which the attributes of the materials, as defined by this specification, are appropriate.

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 2—The dimensionless designators NPS (nominal pipe size) and DN (Diameter Nominal) have been substituted in this standard for such traditional terms as “nominal diameter,” “size,” and “nominal size.”

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.*

2. Referenced Documents

2.1 *ASTM Standards:*³

- [A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels](#)
- [A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe](#)
- [E112 Test Methods for Determining Average Grain Size](#)

¹ 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.

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

³ 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.

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



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, Titanium, Austenitic Stainless Steel and Similar Alloys

2.2 Other Standards:

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing⁴

3. Ordering Information

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

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

3.1.2 Name of material (seamless austenitic steel pipe),

TABLE 1 Chemical Requirements

Table with 15 columns: Grade, UNS Designation, Carbon, Manganese, Phosphorus, Sulfur, Silicon, Nickel, Chromium, Molybdenum, Titanium, Columbium-Niobium, Tantalum, Nitrogen, and Others. It lists various grades like TP304, TP304H, TP304N, etc., with their respective chemical composition ranges.

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

^BThe terms Niobium (Nb) and Columbium (Cb) are alternative names for the same element.

^CThe method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

^DThe titanium content shall be not less than five times the carbon content and not more than 0.70 %.

^EThe titanium content shall be not less than four times the carbon content and not more than 0.70 %.

^FThe columbium content shall be not less than ten times the carbon content and not more than 1.10 %.

^GThe columbium content shall be not less than eight times the carbon content and not more than 1.10 %.

^HThe columbium content shall not be less than 15 times the carbon content.

^IThis grade is intended for special purpose applications.

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

- 3.1.3 Grade (**Table 1**),
- 3.1.4 Size (nominal size, or outside diameter and schedule number or average wall thickness),
- 3.1.5 Lengths (specific or random), (Permissible Variations in Length Section of Specification **A999/A999M**),
- 3.1.6 End finish (Ends Section of Specification **A999/A999M**),
- 3.1.7 Optional requirements (Section **8**) (see Hydrostatic Test Requirements Section and the Permissible Variation in Weight for Seamless Pipe Section for weighing individual lengths, of Specification **A999/A999M**), (see **9.6**, repairing by welding; **13.3**, die stamping),
- 3.1.8 Test report required (Certification Section of Specification **A999/A999M**),
- 3.1.9 Specification designation, and
- 3.1.10 Special requirements or any supplementary requirements selected, or both.

4. General Requirements

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

5. Materials and Manufacture

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

5.2 Heat Treatment:

5.2.1 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."

5.2.2 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.

5.2.3 *Grades TP304, TP304N, TP304LN, TP316, TP316N, TP316LN, TP321, TP347, TP347LN, 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.

5.2.3.1 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."

5.2.4 *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].

5.2.5 *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.

5.2.6 *Grade S31266*—Heat treatment shall consist of heating to a temperature in the range of 2100 °F [1150 °C] minimum and quenching in water or rapidly cooling by other means.

5.3 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).

5.4 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.

6. Chemical Composition

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

7. Product Analysis

7.1 At the request of the purchaser, an analysis of one billet from each heat or two pipes from each lot shall be made by the manufacturer. A lot of pipe shall consist of the number of lengths as a function of size, as shown below, of the same size and wall thickness from any one heat of steel:

NPS [DN] Designator	Lengths of Pipe in Lot
Under NPS 2 [DN 50]	400 or fraction thereof
NPS 2 [DN 50] to NPS 5 [DN 125], incl	200 or fraction thereof
Over NPS 5 [DN 125]	100 or fraction thereof

7.2 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.

7.3 If the analysis of one of the tests specified in Section 8 does not conform to the requirements specified in Section 6, 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.

8. Tensile Requirements

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

9. Workmanship, Finish, and Appearance

9.1 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 9.2.

9.2 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:

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

9.2.2 Repaired in accordance with the repair welding provisions of 9.6.

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

9.2.4 Rejected.

9.3 To provide a workmanlike finish and basis for evaluating conformance with 9.2, the pipe manufacturer shall remove by grinding the following:

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



TABLE 2 Tensile Requirements

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, TP316H, TP316LN, TP347, TP347H, TP347LN, 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 ≤0.375 in. [9.50 mm]	75 [515]	30 [205]	35	25
>0.375 in. [9.50 mm] ^B	70 [480]	25 [170]	35	25
S31266	109 [750]	61 [420]	35	25

^AFor grade TP304, NPS8 or larger, and in schedules 140 and heavier, the required minimum tensile strength shall be 70 ksi [480 MPa].

^BPrior 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 0.375 in. [9.5 mm].

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

9.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 9.1 to be deeper than 5 % of the nominal wall thickness.

9.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 9.2 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.

9.5 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.

9.5.1 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.

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

9.7 The finished pipe shall be reasonably straight.

9.8 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.

10. Hydrostatic or Nondestructive Electric Test

10.1 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.

10.2 *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 10.3 and 10.4.

10.3 For pipe sizes NPS 24 [DN 600] 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."

10.4 *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 that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

10.4.1 The following information is for the benefit of the user of this specification:

10.4.1.1 The reference standards defined in 10.10.1 through 11.10.4 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

10.4.1.2 The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep, defects.

10.4.1.3 The eddy-current testing (ET) referenced in Practice E426 has the capability of detecting significant discontinuities, especially the short abrupt type.

10.4.1.4 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

10.5 *Time of Examination*—Nondestructive testing for specification acceptance shall be performed after all mechanical processing, heat treatments, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

10.6 *Surface Condition:*

10.6.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

10.6.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

10.7 *Extent of Examination:*

10.7.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except as in 5.2.

10.7.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

10.8 *Operator Qualifications*—The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent recognized and documented standard.

10.9 *Test Conditions:*

10.9.1 For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide good signal-to-noise ratio.

10.9.2 The maximum eddy-current coil frequency used shall be as follows:

Specified Wall Thickness, in. [mm]	Maximum Frequency, KHz
<0.050 [1.25]	100
0.050 to 1.50 [1.25 to 3.80]	50
>0.150 [3.80]	10

10.9.3 *Ultrasonic*—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. [38 mm].

10.9.3.1 If the equipment contains a reject notice filter setting, this shall remain off during calibration and testing unless linearity can be demonstrated at that setting.

10.10 *Reference Standards:*

10.10.1 Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS, or outside diameter and schedule or wall thickness), surface finish, and heat treatment condition as the pipe to be examined.

10.10.2 *For Ultrasonic Testing*, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E213, at the option of the manufacturer. The depth of each notch shall not exceed 12½ % of the specified nominal wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater. The width of the notch shall not exceed twice the depth. Notches shall be placed on both the OD and ID surfaces.

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

10.10.3.1 *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 holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. One hole shall be drilled in the weld, if visible. Alternately, the producer of welded pipe may choose to drill one hole in the weld and run the calibration standard through the test coils three times with the weld turned at 120° on each pass. The hole diameter shall vary with NPS as follows:

NPS [DN] Designator	Hole Diameter
above ½ to 1¼ [15 to 32]	0.039 in. [1 mm]
above 1¼ to 2 [32 to 50]	0.055 in. [1.4 mm]
above 2 to 5 [50 to 125]	0.071 in. [1.8 mm]
above 5 [125]	0.087 in. [2.2 mm]
	0.106 in. [2.7 mm]

10.10.3.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼-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 12½ % of the specified nominal wall thickness of the pipe or 0.004 in. [0.102 mm], whichever is greater.

10.10.3.3 *Longitudinal Notch*—A notch 0.031 in. [0.8 mm] 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 12½ % of the specified wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

10.10.3.4 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

10.11 *Standardization Procedure:*

10.11.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h. More frequent standardization may be performed at the manufacturer’s option or may be required upon agreement between the purchaser and the manufacturer.