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An American National Standard

# Standard Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service[1]

This standard is issued under the fixed designation A 335/A 335M; 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 (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope

1.1 This specification[2] covers nominal (average) wall seamless alloy-steel pipe intended for high-temperature service. Pipe ordered to this specification shall be suitable for bending, flanging (vanstoning), and similar forming operations, and for fusion welding. Selection will depend upon design, service conditions, mechanical properties, and high-temperature characteristics.

1.2 Several grades of ferritic steels (Note 1) are covered. Their compositions are given in Table 1.

NOTE 1—Ferritic steels in this specification are defined as low- and intermediate-alloy steels containing up to and including 10 % chromium.

1.3 Supplementary requirements (S1 to S7) of an optional nature are provided. These supplementary requirements call for additional tests to be made, and when desired, shall be so stated in the order together with the number of such tests required.

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 are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

NOTE 2—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:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes[3]

A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe[3]

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing[4]

E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation[4]

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings[5]

E 527 Practice for Numbering Metals and Alloys (UNS)[3]

E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products[4]

2.2 *Other Documents:*

SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification[6]

SAE J 1086 Practice for Numbering Metals and Alloys (UNS)[7]

## 3. Ordering Information

3.1 Orders for material under 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 alloy steel pipe),

3.1.3 Grade (Table 1),

3.1.4 Manufacture (hot-finished or cold-drawn),

3.1.5 Size (NPS or outside diameter and schedule number or average wall thickness),

3.1.6 Length (specific or random),

3.1.7 End finish (Ends Section of Specification A 999/A 999M),

3.1.8 Optional requirements (Section 8, 11 and 12 of this specification. See the Sections on Hydrostatic Test Requirements and Permissible Variation in Weight for Seamless Pipe in Specification A 999/A 999M),

3.1.9 Test report required (Certification Section of Specification AA 999/A 999M),

3.1.10 Specification designation, and

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

[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-335 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

[6] Available from the American Society for Nondestructive Testing, 1711 Arlingate Plaza, PO Box 28518, Columbus, OH 43228-0518.

[7] Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

**TABLE 1 Chemical Requirements**

| Grade | UNS Designation[A] | Composition, % | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Carbon | Manganese | Phosphorus, max | Sulfur, max | Silicon | Chromium | Molybdenum | Others |
| P1 | K11522 | 0.10–0.20 | 0.30–0.80 | 0.025 | 0.025 | 0.10–0.50 | . . . | 0.44–0.65 | . . . |
| P2 | K11547 | 0.10–0.20 | 0.30–0.61 | 0.025 | 0.025 | 0.10–0.30 | 0.50–0.81 | 0.44–0.65 | . . . |
| P5 | K41545 | 0.15 max | 0.30–0.60 | 0.025 | 0.025 | 0.50 max | 4.00–6.00 | 0.45–0.65 | . . . |
| P5b | K51545 | 0.15 max | 0.30–0.60 | 0.025 | 0.025 | 1.00–2.00 | 4.00–6.00 | 0.45–0.65 | . . . |
| P5c | K41245 | 0.12 max | 0.30–0.60 | 0.025 | 0.025 | 0.50 max | 4.00–6.00 | 0.45–0.65 | . . .[B] |
| P9 | S50400 | 0.15 max | 0.30–0.60 | 0.025 | 0.025 | 0.25–1.00 | 8.00–10.00 | 0.90–1.10 | . . . |
| P11 | 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 | . . . |
| P12 | K11562 | 0.05–0.15 | 0.30–0.61 | 0.025 | 0.025 | 0.50 max | 0.80–1.25 | 0.44–0.65 | . . . |
| P15 | K11578 | 0.05–0.15 | 0.30–0.60 | 0.025 | 0.025 | 1.15–1.65 | . . . | 0.44–0.65 | . . . |
| P21 | K31545 | 0.05–0.15 | 0.30–0.60 | 0.025 | 0.025 | 0.50 max | 2.65–3.35 | 0.80–1.06 | . . . |
| P22 | K21590 | 0.05–0.15 | 0.30–0.60 | 0.025 | 0.025 | 0.50 max | 1.90–2.60 | 0.87–1.13 | . . . |
| P23 | K41650 | 0.04–0.10 | 0.10–0.60 | 0.030 max | 0.010 max | 0.50 max | 1.90–2.60 | 0.05–0.30 | V 0.20–0.30<br>Cb 0.02–0.08<br>B 0.0005–0.006<br>N 0.030 max<br>Al 0.030 max<br>W 1.45–1.75 |
| P91 | K91560 | 0.08–0.12 | 0.30–0.60 | 0.020 | 0.010 | 0.20–0.50 | 8.00–9.50 | 0.85–1.05 | V 0.18–0.25<br>N 0.030–0.070<br>Ni 0.40 max<br>Al 0.04 max<br>Cb 0.06–0.10 |
| P92 | K92460 | 0.07–0.13 | 0.30–0.60 | 0.020 | 0.010 | 0.50 max | 8.50–9.50 | 0.30–0.60 | V 0.15–0.25<br>N 0.03–0.07<br>Ni 0.40 max<br>Al 0.04 max<br>Cb 0.04–0.09<br>W 1.5–2.00<br>B 0.001–0.006 |
| P122 | K92930 | 0.07–0.14 | 0.70 max | 0.020 | 0.010 | 0.50 max | 10.00–12.50 | 0.25–0.60 | V 0.15–0.30<br>W 1.50–2.50<br>Cu 0.30–1.70<br>Cb 0.04–0.10<br>B 0.0005–0.005<br>N 0.040–0.100<br>Ni 0.50 max<br>Al 0.040 max |
| P911 | K91061 | 0.09–0.13 | 0.30–0.60 | 0.020 max | 0.010 max | 0.10–0.50 | 8.50–10.50 | 0.90–1.10 | V 0.18–0.25<br>Ni 0.40 max<br>Cb 0.060–0.10<br>B 0.0003–0.006<br>N 0.04–0.09<br>Al 0.04 max<br>W 0.90–1.10 |

[A] New designation established in accordance with Practice E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).
[B] Grade P 5c shall have a titanium content of not less than 4 times the carbon content and not more than 0.70 %; or a columbium content of 8 to 10 times the carbon content.



## 4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M, unless otherwise provided herein.

## 5. Materials and Manufacture

5.1 Pipe may be either hot finished or cold drawn with the finishing treatment as required in 5.3.

5.2 *Grade P2 and P12*—The steel shall be made by coarse-grain melting practice. Specific limits, if any, on grain size or deoxidation practice shall be a matter of agreement between the manufacturer and purchaser.

5.3 *Heat Treatment*:

5.3.1 All pipe of grades shown in Table 1 except P5c, P23 P91, P92, P122, and P911 as provided in 5.3.2, shall be reheated and furnished in the full-annealed, isothermal annealed, or normalized and tempered condition. If furnished in the normalized and tempered condition, the minimum tempering temperature for Grades P5, P5b, P9, P21, and P22 shall be 1250°F [675°C], the minimum tempering temperature for Grades P1, P2, P11, P12, and P 15 shall be 1200°F [650°C].

NOTE 3—It is recommended that the temperature for tempering should be at least 100°F [50°C] above the intended service temperature; consequently, the purchaser should advise the manufacturer if the service temperature is to be over 1100°F [600°C].

5.3.2 Pipe of Grades P1, P2, and P12, either hot finished or cold drawn, may be given a final heat treatment at 1200°F [650°C] to 1300°F [705°C] instead of heat treatments specified in 5.3.1.

5.3.3 All pipe of Grades P5c shall be given a final heat treatment in the range from 1325°F [715°C] to 1375°F [745°C].

NOTE 4—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. Therefore, operations involving heating such steels above their critical temperatures, such as welding, flanging, and hot bending, should be followed by suitable heat treatment.

5.3.4 Grades P92 and P911 shall be normalized at 1900°F [1040°C] minimum and tempered at 1350°F [730°C] minimum as a final heat treatment.

5.3.5 Grade P122 shall be normalized at 1900°F [1040°C] minimum, and tempered at 1350°F [730°C] minimum as a final heat treatment.

5.3.6 Grade P23 shall be normalized at 1900°F [1040°C] minimum with air cooling or accelerated cooling and tempered at 1350°F [730°C] minimum as a final heat treatment.

5.4 Except when Supplementary Requirement S7 is specified by the purchaser, Grade P91 shall be normalized at 1900°F [1040°C] minimum, and tempered at 1350°F [730°C] minimum as a final heat treatment. Alternatively, liquid quenching and tempering is allowed for thicknesses above 3 in. when mutually agreed upon between the manufacturer and the purchaser. In this case the pipe shall be quenched from 1900°F [1040°C] minimum and tempered at 1350°F [730°C] minimum as final heat treatment.

## 6. Chemical Composition

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

## 7. Workmanship, Finish, and Appearance

7.1 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 ensure compliance with 7.2

7.2 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:

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

7.2.2 Repaired in accordance with the repair welding provisions of 7.6.

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

7.2.4 Rejected.

7.3 To provide a workmanlike finish and basis for evaluating conformance with 7.2, the pipe manufacturer shall remove by grinding the following:

7.3.1 Mechanical marks, abrasions (Note 5) and pits, any of which imperfections are deeper than 1⁄16 in. [1.6 mm].

NOTE 5—Marks and abrasions are defined as cable marks, dinges, guide marks, roll marks, ball scratches, scores, die marks, and the like.

7.3.2 Visual imperfections, commonly referred to as scabs, seams, laps, tears, or slivers, found by exploration in accordance with 7.1 to be deeper than 5 % of the nominal wall thickness.

7.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 7.2 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.

7.5 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.

7.5.1 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.

7.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 999/A 999M.

7.7 The finished pipe shall be reasonably straight.

## 8. Product Analysis

8.1 At the request of the purchaser, an analysis of two pipes from each lot shall be made by the manufacturer. A lot (Note 6) of pipe shall consist of the following:

| NPS Designator | |
|---|---|
| Under 2 | 400 or fraction thereof |
| 2 to 5 | 200 or fraction thereof |
| 6 and over | 100 or fraction thereof |

NOTE 6—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 For grade P 91 the carbon content may vary for the product analysis by −0.01 % and +0.02 % from the specified range as per Table 1.

8.4 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in 6.1, 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 and Hardness Requirements

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

9.2 Table 3 lists elongation requirements.

9.3 Pipe of Grade P122 shall have a hardness not exceeding 250 HB/265 HV [25 HRC].

9.4 Table 4 gives the computed minimum elongation values for each 1⁄32-in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values above, the minimum elongation value is determined by the following formula:

| Direction of Test | Equation[B] |
|---|---|
| Longitudinal, all grades except P23, P91, P122, and P911 | E = 48t + 15.00 [*E* = 1.87*t* + 15.00] |
| Transverse | E = 32t + 10.00 [*E* = 1.25*t* + 10.00] |
| Longitudinal, P23, P91, P122, and P911 | E = 32t + 10.00 [*E* = 1.25*t* + 10.00] |

where:
*E* = elongation in 2 in. or 50 mm, %, and
*t* = actual thickness of specimens, in. [mm].

**TABLE 2 Tensile Requirements**

| Identification Symbol | P1, P2 | P12 | P23 | P91 | P92, P911 | P122 | All Others |
|---|---|---|---|---|---|---|---|
| Tensile strength, min: | | | | | | | |
| ksi | 55 | 60 | 74 | 85 | 90 | 90 | 60 |
| MPa | 380 | 415 | 510 | 585 | 620 | 620 | 415 |
| Yield strength, min: | | | | | | | |
| ksi | 30 | 32 | 58 | 60 | 64 | 58 | 30 |
| MPa | 205 | 220 | 400 | 415 | 440 | 400 | 205 |

**TABLE 3 Elongation Requirements**

| | Elongation Requirements, All grades except P23, P91, P92, and P911 | | P23, P91, P122, and P911 | |
|---|---|---|---|---|
| | Longitudinal | Transverse | Longitudinal | Transverse |
| Elongation in 2 in. or 50 mm, (or 4*D*), min, %: | | | | |
| Basic minimum elongation for wall 5/16 in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section | 30 | 20 | 20 | . . . |
| When standard round 2-in. or 50-mm gage length or proportionally smaller size specimen with the gage length equal to 4*D* (4 times the diameter) is used | 22 | 14 | 20 | 13 |
| For strip tests a deduction for each 1/32-in. [0.8 mm] decrease in wall thickness below in. [8 mm] from the basic minimum elongation of the following percentage points shall be made | 1.50[A] | 1.00[A] | 1.00[A] | . . . |

[A] Table 4 gives the calculated minimum values.

**TABLE 4 Computed Minimum Elongation Values**

| Wall Thickness | | Elongation in 2 in. or 50 mm, min, % | | |
|---|---|---|---|---|
| | | All grades except P23, P91, P92, P122, and P911 | | |
| in. | mm | Longitudinal | Transverse | Longitudinal |
| 5/16 (0.312) | 8 | 30 | 20.0 | 20 |
| 9/32 (0.281) | 7.2 | 29 | 19.0 | 19 |
| 1/4 (0.250) | 6.4 | 27 | 18.0 | 18 |
| 7/32 (0.219) | 5.6 | 26 | . . . | 17 |
| 3/16 (0.188) | 4.8 | 24 | . . . | 16 |
| 5/32 (0.156) | 4 | 22 | . . . | 15 |
| 1/8 (0.125) | 3.2 | 21 | . . . | 14 |
| 3/32 (0.094) | 2.4 | 20 | . . . | 13 |
| 1/16 (0.062) | 1.6 | 18 | . . . | 12 |

## 10. Permissible Variations in Diameter

10.1 Variations in outside diameter shall not exceed those specified in Table 5.

## 11. Hydrostatic Test

11.1 Each length of pipe shall be subjected to the hydrostatic test, except as provided for in 11.2 or 11.3.

**TABLE 5 Variations in Outside Diameter Permissible Variations in Outside Diameter**

| NPS Designator | Over | | Under | |
|---|---|---|---|---|
| | in. | mm | in. | mm |
| 1/8 to 1 1/2, incl. | 1/64 (0.015) | 0.40 | 1/64 (0.015) | 0.40 |
| Over 1 1/2 to 4, incl. | 1/32 (0.031) | 0.79 | 1/32 (0.031) | 0.79 |
| Over 4 to 8, incl. | 1/16 (0.062) | 1.59 | 1/32 (0.031) | 0.79 |
| Over 8 to 12, incl. | 3/32 (0.093) | 2.38 | 1/32 (0.031) | 0.79 |
| Over 12 | ± 1 % | | | |

11.2 Unless otherwise specified in the purchase order, each length of pipe shall, at the option of the manufacturer, be subjected to the nondestructive electric test as shown in Section 12 in lieu of the hydrostatic test.

11.3 When specified by the purchaser, pipe shall be furnished without hydrostatic test and without nondestructive examination.

11.4 When specified by the purchaser, pipe shall be furnished with both the hydrostatic test and a nondestructive examination having been performed.



## 12. Nondestructive Examination

12.1 When selected by the manufacturer or when specified in the order, as an alternative to the hydrostatic test (11.2), or when secified in the purchase order in addition to the hydrostatic test (11.4), each pipe shall be examined by a nondestructive examination method in accordance with Practice E 213, Practice E 309 or Practice E 570. 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.

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

12.2.1 The reference standards defined in 12.8 are convenient standards for standardization of nondestructive examination equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

12.2.2 Ultrasonic examination can be performed to detect both longitudinally and transversely oriented discontinuities. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep imperfections.

12.2.3 The eddy current examination referenced in this specification has the capability to detect significant discontinuities, especially of the short abrupt type.

12.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. It should be recognized that different techniques should be employed to detect differently oriented imperfections.