Designation: A335/A335M – 24b

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

This standard is issued under the fixed designation A335/A335M; 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 U.S. Department of Defense.*

## 1. Scope*

1.1 This specification[2] covers nominal wall and minimum wall seamless ferritic 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 (see 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 S9) of an optional nature are provided. Supplementary requirements S1 through S6 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 as applicable.

1.4 The values stated in either SI units or inch-pound 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 designator NPS (nominal pipe size) has 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]

A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E92 Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E309 Practice for Eddy Current Examination of Steel Tubular Products

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

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

E570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *ASME Standard:*

B36.10M Welded and Seamless Wrought Steel Pipe

2.3 *AWS Specifications*[4]

A5.5/A5.5M Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

A5.23/A5.23M Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding

A5.28/A5.28M Specification for Low-Alloy Steel Electrodes for Gas Shielded Arc Welding

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

[4] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, http://www.aws.org.

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

**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 | K90941 | 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 | K40712 | 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>Nb[F] 0.02–0.08<br>B 0.0010–0.006<br>N 0.015 max<br>Al 0.030 max<br>W 1.45–1.75<br>Ni 0.40 max<br>Ti 0.005–0.060<br>Ti/N ≥ 3.5[C] |
| P24 | K30736 | 0.05–0.10 | 0.30–0.70 | 0.020 | 0.010 | 0.15–0.45 | 2.20–2.60 | 0.90–1.10 | V 0.20–0.30<br>Ti 0.06–0.10<br>N 0.012 max<br>Al 0.02 max<br>B 0.0015–0.007 |
| P36 | K21001 | 0.10–0.17 | 0.80–1.20 | 0.030 max | 0.025 max | 0.25–0.50 | 0.30 max | 0.25–0.50 | Ni 1.00-1.30<br>Cu 0.50-0.80<br>Nb[F] 0.015-0.045<br>V 0.02 max<br>N 0.02 max<br>Al 0.050 max |
| P91 Type 1 | K90901 | 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 0.02 max<br>Nb[F] 0.06–0.10<br>Ti 0.01 max<br>Zr 0.01 max |
| P91 Type 2 | K90901 | | | | | | | | V |
| Heat | | 0.08–0.12 | 0.30–0.50[D] | 0.020[D] | 0.005[D] | 0.20–0.40[D] | 8.00–9.50[D] | 0.85–1.05 | Heat 0.18–0.25 |
| Product | | 0.07–0.13 | | | | | | 0.80–1.05 | Product 0.16–0.27<br>Ni 0.20 max[D]<br>Al 0.020 max[D]<br>N 0.035–0.070[D]<br>N/Al ratio ≥4.0<br>Nb[F]<br>Heat 0.06–0.10<br>Product 0.05–0.11<br>Ti 0.01 max[D]<br>Zr 0.01 max[D]<br>Sn 0.010 max[D]<br>Sb 0.003 max[D]<br>As 0.010 max[D]<br>B 0.001 max[D]<br>W 0.05 max[D]<br>Cu 0.10 max[D] |
| 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 0.02 max<br>Nb[F] 0.04–0.09<br>W 1.5–2.00<br>B 0.001–0.006<br>Ti 0.01 max<br>Zr 0.01 max |

**TABLE 1** *Continued*

| Grade | UNS Designation[A] | Composition, % | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Carbon | Manganese | Phosphorus, max | Sulfur, max | Silicon | Chromium | Molybdenum | Others |
| P93 | K91350 | 0.05–0.10 | 0.20–0.70 | 0.020 | 0.008 | 0.05–0.50 | 8.50–9.50 | . . . | V 0.15–0.30<br>W 2.5–3.5<br>Co 2.5–3.5<br>Ni 0.20 max<br>Nb[F] + Ta 0.05–0.12<br>Nd 0.010–0.060<br>B 0.007–0.015<br>Al 0.030 max<br>N 0.005–0.015<br>O 0.0050 max |
| P115 Heat | K91060 | 0.08–0.13 | 0.20–0.50 | 0.020 | 0.005 | 0.15–0.45 | 10.0–11.0 | 0.40–0.60 | V 0.18–0.25<br>N 0.030–0.070<br>Ni 0.25 max<br>Al 0.02 max<br>Nb 0.02–0.06<br>W 0.05 max<br>B 0.001 max<br>Ti 0.01 max<br>Zr 0.01 max<br>Cu 0.10 max<br>As 0.010 max<br>Sn 0.010 max<br>Sb 0.003 max<br>N/Al ratio min 4.0<br>CNB[E], max 10.5 |
| Product | | 0.07–0.14 | 0.20–0.50 | 0.020 | 0.005 | 0.15–0.45 | 10.0–11.0 | 0.37–0.63 | V 0.16–0.27<br>N 0.030–0.070<br>Ni 0.25 max<br>Al 0.02 max<br>Nb 0.02–0.07<br>W 0.05 max<br>B 0.001 max<br>Ti 0.01 max<br>Zr 0.01 max<br>Cu 0.10 max<br>As 0.010 max<br>Sn 0.010 max<br>Sb 0.003 max |
| P122 | K92930 | 0.07–0.14 | 0.70 max | 0.020 | 0.010 | 0.50 max | 10.00–11.50 | 0.25–0.60 | V 0.15–0.30<br>W 1.50–2.50<br>Cu 0.30–1.70<br>Nb[F] 0.04–0.10<br>B 0.0005–0.005<br>N 0.040–0.100<br>Ni 0.50 max<br>Al 0.020 max<br>Ti 0.01 max<br>Zr 0.01 max |
| P128 | K91421 | 0.12 – 0.17 | 0.30 – 0.80 | 0.02 | 0.01 | 0.20 – 0.60 | 10.50 – 12.00 | 0.20 – 0.60 | V 0.15 – 0.30<br>Ni 0.10 – 0.40<br>B 0.008 – 0.015<br>N 0.002 – 0.020<br>Co 1.50 – 2.20<br>Al 0.02 max<br>Cu 0.15 max<br>W 1.50 – 2.20<br>Nb 0.02 – 0.06 |
| P911 | K91061 | 0.09–0.13 | 0.30–0.60 | 0.020 max | 0.010 max | 0.10–0.50 | 8.5–9.5 | 0.90–1.10 | V 0.18–0.25<br>Ni 0.40 max<br>Nb[F] 0.060–0.10<br>B 0.0003–0.006<br>N 0.04–0.09<br>Al 0.02 max<br>W 0.90–1.10<br>Ti 0.01 max<br>Zr 0.01 max |
| P921 | K91201 | 0.08–0.12 | 0.5–0.7 | 0.03 | 0.02 | 1.6–2.2 | 8.0–9.5 | 0.8–1.1 | Ni 0.8–1.4<br>N 0.02–0.05<br>Al 0.04 max<br>Cu 0.8–1.4 |

[A] New designation established in accordance with Practice E527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).
[B] Grade P5c shall have a titanium content of not less than 4 times the carbon content and not more than 0.70 %; or a niobium content of 8 to 10 times the carbon content.

[C]Alternatively, in lieu of this ratio minimum, the material shall have a minimum hardness of 275 HV in the hardened condition, defined as after austenitizing and cooling to room temperature but prior to tempering. Hardness testing shall be performed at mid-thickness of the product. Hardness test frequency shall be two samples of product per heat treatment lot and the hardness testing results shall be reported on the material test report.
[D]Applies to both heat and product analyses.
[E]Chromium-Nickel Balance is defined as CNB = (Cr + 6Si + 4Mo + 1.5W + 11V + 5Nb + 9Ti + 12Al) – (40C + 30N + 4Ni + 2Mn + 1CU).
[F]The terms Niobium (Nb) and Columbium (Cb) are alternate names for the same element.

A5.29/A5.29M Low-Alloy Steel Electrodes for Flux Cored Arc Welding

2.4 *Other Documents:*

SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification[5]

SAE J 1086 Practice for Numbering Metals and Alloys (UNS)[6]

## 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, metres, 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 using one of the following:

3.1.5.1 NPS and schedule number,

3.1.5.2 Outside diameter and nominal wall thickness,

3.1.5.3 Outside diameter and minimum wall thickness,

3.1.5.4 Inside diameter and nominal wall thickness, and

3.1.5.5 Inside diameter and minimum wall thickness.

3.1.6 Length (specific or random),

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

3.1.8 Optional requirements (Section 8, 12, and 13 of this specification. See the Sections on Hydrostatic Test Requirements and Permissible Variation in Weight for Seamless Pipe in Specification A999/A999M),

3.1.9 Specification designation, and

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

3.1.11 The flattening or bend test shall be performed on 5 % of the pipe (or fewer in accordance with 14.2) unless Supplementary Requirement S3 is specified.

## 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 Pipe may be either hot finished or cold drawn with the finishing treatment as required in 5.2.

5.2 *Heat Treatment:*

5.2.1 All pipe shall be reheated for heat treatment and heat treated in accordance with the requirements of Table 2.

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].

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.

## 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 (see 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

[5] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

[6] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

**TABLE 2 Heat Treatment Requirements[A]**

| Grade | Heat Treat Type | Normalizing Temperature, min or range °F [°C] | Cooling Media | Subcritical Annealing or Tempering Temperature, min or range °F [°C] |
|---|---|---|---|---|
| P1 | full or isothermal anneal or | . . . | . . . | . . . |
| | normalize and temper or | . . . | . . . | 1200 [650] |
| | subcritical anneal | . . . | . . . | 1200–1300 [650–705] |
| P2 | full or isothermal anneal or | . . . | . . . | . . . |
| | normalize and temper or | . . . | . . . | 1250 [675] |
| | subcritical anneal | . . . | . . . | 1200–1300 [650–705] |
| P5 | full or isothermal anneal or | . . . | . . . | . . . |
| | normalize and temper | . . . | . . . | 1250 [675] |
| P5b | full or isothermal anneal or | . . . | . . . | . . . |
| | normalize and temper | . . . | . . . | 1250 [675] |
| P5c | subcritical anneal | . . . | . . . | 1325–1375 [715–745] |
| P9 | full or isothermal anneal or | . . . | . . . | . . . |
| | normalize and temper | . . . | . . . | 1250 [675] |
| P11 | full or isothermal anneal or | . . . | . . . | . . . |
| | normalize and temper | . . . | . . . | 1200 [650] |
| P12 | full or isothermal anneal or | . . . | . . . | . . . |
| | normalize and temper or | . . . | . . . | 1200 [650] |
| | subcritical anneal | . . . | . . . | 1200–1300 [650–705] |
| P15 | full or isothermal anneal or | . . . | . . . | . . . |
| | normalize and temper | . . . | . . . | 1200 [650] |
| P21 | full or isothermal anneal or | . . . | . . . | . . . |
| | normalize and temper | . . . | . . . | 1250 [675] |
| P22 | full or isothermal anneal or | . . . | . . . | . . . |
| | normalize and temper | . . . | . . . | 1250 [675] |
| P23 | normalize and temper | 1900–1975 [1040–1080] | air or accelerated cooling | 1350–1470 [730–800] |
| P24 | normalize and temper | 1800–1870 [980–1020] | air or accelerated cooling | 1350–1420 [730–770] |
| P36 | normalize and temper[B] | 1650 [900] | . . . | 1100 [595] |
| P91 Type 1 and Type 2 | normalize and temper or | 1900–1975 [1040–1080] | . . . | 1350–1470 [730–800][C] |
| | quench and temper | 1900–1975 [1040–1080] | . . . | 1350–1470 [730–800] |
| P92 | normalize and temper | 1900–1975 [1040–1080] | [D] | 1350–1470 [730–800] |
| P93 | normalize and temper | 1960–2140 [1070–1170] | . . . | 1380–1455 [750–790] |
| P115 | normalize and temper | 1920–2010 [1050–1100] | [D] | 1380–1455 [750–790] |
| P122 | normalize and temper | 1900–1975 [1040–1080] | . . . | 1350–1470 [730–800] |
| P128 | normalize and temper | 1975–2140 [1080–1170] | air | 1400–1470 [760–800] |
| P911 | normalize and temper | 1900–1975 [1040–1080] | [D] | 1365–1435 [740–780] |
| P921 | normalize and temper | 1670–1740 [910–950] | air | 1350–1420 [730–770] |

[A] Where ellipses (…) appear in this table there is no requirement.
[B] Alternatively, Grade P36, Class 2 shall be cooled from the austenitizing temperature by accelerated cooling in air or by liquid quenching.
[C] Except when Supplementary Requirement S7 is specified by the purchaser.
[D] Accelerated cooling from the normalizing temperature shall be permitted for section thicknesses greater than 3 in. [75 mm].

specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

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

7.6.1 All repair welds in P91 shall be made with one of the following welding processes and consumables: SMAW, A5.5/A5.5M E90XX-B9; SAW, A5.23/A5.23M EB9 + neutral flux; GTAW, A5.28/A5.28M ER90S-B9; and FCAW A5.29/A5.29M E91T1-B9. In addition, the sum of the Ni+Mn content of all welding consumables used to weld repair P91 Type 1 and Type 2 shall not exceed 1.0 %.

7.6.2 All repair welds in P92, P93, P911, and P122, shall be made using welding consumables meeting the chemical requirements for the grade in Table 1.

7.6.3 After weld repair, Grades P23, P91 Type 1 and Type 2, P92, and P122 shall be heat treated at 1350–1470 °F [730–800 °C].

7.6.4 After weld repair, Grade P911 shall be heat treated at 1365–1435 °F [740–780 °C].

7.6.5 After weld repair, Grade P24 shall be heat treated at 1350–1420 °F [730–770 °C].

7.6.6 After weld repair, Grade P93 shall be heat treated to 1350–1455 °F [730–790 °C].

7.6.7 After weld repair, Grade P115 shall be heat treated at 1345–1435 °F [730–780 °C].

7.6.8 After weld repair, Grade P128 shall be heat treated at 1400–1470 °F [760–800 °C].

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 as defined hereafter shall be made by the manufacturer. A lot is all pipe of the same nominal size and wall thickness (schedule) which is produced from the same heat of steel and shall be limited as follows:

| NPS Designator | Maximum Number of Lengths in a Lot |
|---|---|
| Under 2 | 400 |
| 2 to 5 | 200 |
| 6 and over | 100 |

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 P91 Type 1 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 3.

9.2 Table 4 lists elongation requirements.

9.3 Table 5 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, P24, P36, P91 Type 1 and Type 2, P92, P921, P93, P115, P122, P128, and P911 | E = 48t + 15.00 [E = 1.87 *t* + 15.00] |
| Transverse, all grades except P23, P24, P36, P91 Type 1 and Type 2, P92, P921, P93, P115, P122, P128, and P911 | E = 32t + 10.00 [E = 1.25 *t* + 10.00] |
| Longitudinal, P23, P24, P91 Type 1 and Type 2, P92, P921, P115, P122, P128, and P911 | E = 32t + 10.00 [E = 1.25 *t* + 10.00] |
| Longitudinal, P36 | E = 32t + 5.0 [E = 1.25 *t* + 5.0] |
| Longitudinal, P93 | E = 32t + 9.0 [E = 1.25 *t* + 9.0] |

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

9.4 Table 6 lists hardness requirements.

9.5 For Grade P91 Type 1 and Type 2, when quenching and tempering has been performed, the tensile and hardness properties shall be met and verified on material taken from the half-thickness location.

## 10. Permissible Variations in Diameter

10.1 For pipe ordered to NPS [DN] or outside diameter, variations in outside diameter shall not exceed those specified in Table 7.

10.2 For pipe ordered to inside diameter, the inside diameter shall not vary more than ± 1 % from the specified inside diameter.

## 11. Permissible Variations in Wall Thickness

11.1 In addition to the implicit limitation of wall thickness for pipe imposed by the limitation on weight in Specification A999/A999M, the wall thickness for pipe at any point shall be within the tolerances specified in Table 8. The minimum wall thickness and outside diameter for inspection for compliance with this requirement for pipe ordered by NPS [DN] and schedule number is shown in ASME B36.10M.

## 12. Hydrostatic Test

12.1 The requirements for grades other than P91 Type 1 and Type 2, P92, P93, P115, P911, P122, and P128 are shown in 12.1.1 – 12.1.4.

12.1.1 Each length of pipe with outside diameter greater than 10 in. [250 mm] and wall thickness less than or equal to 0.75 in. [19 mm], shall be submitted to the hydrostatic test, except as provided for in 12.1.4.

12.1.2 Pipe of all other sizes shall be subjected to the nondestructive electric test as shown in Section 13, except as provided for in 12.1.3 and 12.1.4.

12.1.3 When specified by the purchaser, pipe of all other sizes shall be furnished without the hydrostatic test and without nondestructive examination.

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

12.2 The requirements for grades P91 Type 1 and Type 2, P92, P93, P115, P911, P122, and P128 are shown in 12.2.1 – 12.2.3.

12.2.1 Each length of pipe with outside diameter greater than 10 in. [250 mm] and wall thickness less than or equal to 0.75 in. [19 mm], shall be submitted to both the hydrostatic test and the ultrasonic test as shown in Section 13.

**TABLE 3 Tensile Requirements**

| | Grade | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P1, P2 | P12 | P23 | P24 | P91 Type 1 and Type 2 | P92, P93, P911, P36 Class 1 | P921 | P115 | P122 | P128 | P36 Class 2 | All Others |
| Tensile strength, min: | | | | | | | | | | | | |
| ksi | 55 | 60 | 74 | 85 | 85 | 90 | 109 | 90 | 90 | 94 | 95.5 | 60 |
| MPa | 380 | 415 | 510 | 585 | 585 | 620 | 750 | 620 | 620 | 650 | 660 | 415 |
| Yield strength, min: | | | | | | | | | | | | |
| ksi | 30 | 32 | 58 | 60 | 60 | 64 | 84 | 65 | 58 | 71 | 66.5 | 30 |
| MPa | 205 | 220 | 400 | 415 | 415 | 440 | 580 | 450 | 400 | 490 | 460 | 205 |

**TABLE 4 Elongation Requirements**

| Elongation Requirements | | | | | | |
|---|---|---|---|---|---|---|
| | All grades except P23, P24, P36, P91 Type 1 and Type 2, P92, P921, P93, P115, P122, P128, and P911 | | P23, P24, P91 Type 1 and Type 2, P92, P921, P115, P122, P128, and P911 | | P36 | P93 |
| | Longitudinal | Transverse | Longitudinal | Transverse | Longitudinal | Longitudinal |
| 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 | . . . | 15 | 19 |
| 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] | . . . | 1.00[A] | 1.00[A] |

[A] Table 5 gives the calculated minimum values.

**TABLE 5 Calculated Minimum Elongation Values**

| Wall Thickness | | Elongation in 2 in. or 50 mm, min, % | | | | |
|---|---|---|---|---|---|---|
| | | All grades except P23, P24, P36, P91 Type 1 and Type 2, P92, P921, P93, P115, P122, P128, and P911 | | P23, P24, P91, Type 1 and Type 2, P92, P921, P115, P122, P128 and P911 | P36 | P93 |
| in. | mm | Longitudinal | Transverse | Longitudinal | Longitudinal | Longitudinal |
| 5/16 (0.312) | 8 | 30 | 20 | 20 | 15 | 19 |
| 9/32 (0.281) | 7.2 | 28 | 19 | 19 | 14 | 18 |
| 1/4 (0.250) | 6.4 | 27 | 18 | 18 | 13 | 17 |
| 7/32 (0.219) | 5.6 | 26 | . . . | 17 | 12 | 16 |
| 3/16 (0.188) | 4.8 | 24 | . . . | 16 | 11 | 15 |
| 5/32 (0.156) | 4 | 22 | . . . | 15 | 10 | 14 |
| 1/8 (0.125) | 3.2 | 21 | . . . | 14 | 9 | 13 |
| 3/32 (0.094) | 2.4 | 20 | . . . | 13 | 8 | 12 |
| 1/16 (0.062) | 1.6 | 18 | . . . | 12 | 7 | 11 |

**TABLE 6 Hardness Requirements[A]**

| Grade | Brinell | Vickers | Rockwell |
|---|---|---|---|
| P23 | 220 HBW | 220 HV | 97 HRBW |
| P91 Type 1, Type 2, P115 | 190 to 250 HBW | 196 to 265 HV | 91 HRBW to 25 HRC |
| P24, P36, P92, P93, P122, P911 | 250 HBW | 265 HV | 25 HRC |
| P128 | 265 HBW | 280 HV | 27 HRC |
| P921 | 276 HBW | 290 HV | 26 HRC |

[A] Maximum, unless a range is specified.

12.2.2 Pipe of all other sizes shall be subjected to the nondestructive electric test as shown in Section 13, except as provided for in 12.2.3.

12.2.3 When specified by the purchaser, pipe of all other sizes shall be furnished with both the hydrostatic test and a nondestructive examination having been performed.

**TABLE 7 Permissible Variations in Outside Diameter**

| NPS [DN] Designator | Over | | Under | |
|---|---|---|---|---|
| | in. | mm | in. | mm |
| ⅛ to 1½ [6 to 40], incl. | 1/64 (0.015) | 0.40 | 1/64 (0.015) | 0.40 |
| Over 1½ to 4 [40 to 100], incl. | 1/32 (0.031) | 0.79 | 1/32 (0.031) | 0.79 |
| Over 4 to 8 [100 to 200], incl. | 1/16 (0.062) | 1.59 | 1/32 (0.031) | 0.79 |
| Over 8 to 12 [200 to 300], incl. | 3/32 (0.093) | 2.38 | 1/32 (0.031) | 0.79 |
| Over 12 [300] | ± 1 % of the specified outside diameter | | | |

**TABLE 8 Permitted Variations in Wall Thickness**

| NPS [DN] Designator | Tolerance, % from Specified | |
|---|---|---|
| | Over | Under |
| ⅛ to 2½ [6 to 65] incl., all t/D ratios[A] | 20.0 | 12.5 |
| Above 2½ [65], t/D ≤ 5 %[A] | 22.5 | 12.5 |
| Above 2½ [65], t/D > 5 %[A] | 15.0 | 12.5 |

[A] t = Specified Wall Thickness; D = Specified Outside Diameter.

## 13. Nondestructive Examination

13.1 When required by 12.1.2 or 12.2 above, or when specified in the purchase order in addition to the hydrostatic test (12.2.3), each pipe shall be examined by a nondestructive examination method in accordance with Practice E213, Practice E309, or Practice E570. Except for Grades P91 Type 1 and Type 2, P92, P93, P115, P911, P122, and P128, the type of nondestructive examination shall be at the option of the manufacturer, unless otherwise specified in the order. Grades P91 Type 1 and Type 2, P92, P93, P115, P911, P122, and P128 shall be examined by an examination method in accordance with Practice E213. When specified in the order, pipe of Grades P91 Type 1 and Type 2, P92, P93, P115, P911, P122, and P128 shall be examined by an examination method in accordance with Practices E309 or E570, in addition to the examination method in accordance with Practice E213. 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.

13.2 Following conditions apply in lieu or in addition to those in Specification A999/A999M:

13.2.1 The width of the notch shall not exceed the depth.

13.2.2 If upon any standardization, the reference signal amplitude has decreased by more than 25 % (2 db), the test apparatus shall be considered out of standardization. The test system settings may be changed, or the transducer(s), coil(s) or sensor(s) adjusted, and the unit restandardized, but all pipe tested since the last acceptable standardization shall be re-tested.

13.2.3 Pipes producing a signal equal to or greater than the signal produced by the reference standard shall be subject to one of the following four dispositions:

13.2.3.1 The pipes may be rejected without further examination, at the discretion of the manufacturer.

13.2.3.2 The pipes shall be rejected if the test signal was produced by imperfections which cannot be identified, or was produced by cracks or crack-like imperfections.

13.2.3.3 The pipes may be repaired by grinding (in accordance with 7.2.1), welding (in accordance with 7.6) or sectioning (in accordance with 7.2.3). To be accepted, a repaired pipe must pass the same nondestructive examination by which it was rejected, and it must meet the remaining wall thickness requirements of this specification.

13.2.3.4 If the test signals were produced by visual imperfections such as those listed below, the pipes may be evaluated in accordance with the provisions of Section 7:

*(a)* Scratches,
*(b)* Surface roughness,
*(c)* Dings,
*(d)* Straightener marks,
*(e)* Cutting chips,
*(f)* Steel die stamps,
*(g)* Stop marks, or
*(h)* Pipe reducer ripple.

## 14. Mechanical Tests Required

14.1 *Lot*—For mechanical testing, a lot is all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace; when final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge.

14.2 *Transverse or Longitudinal Tension Test and Flattening or Bend Test*—For material heat treated in a batch-type furnace, tests shall be made on 5 % of the pipe from each treated lot. For small lots, at least 1 pipe shall be tested. For material heat treated by the continuous process, tests shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than 2 pipe. Unless otherwise specified, the flattening test or bend test shall be chosen at the manufacturer's option.

14.3 *Hardness Test:*

14.3.1 The Vickers hardness testing shall be made in accordance with Test Method E92.

14.3.2 For pipes with wall thickness 0.200 in. [5.1 mm] or over, either the Brinell, Rockwell, or Vickers hardness test shall be used. When Brinell hardness testing is used, a 10-mm ball with 3000, 1500, or 500-kg load shall be used at the option of the manufacturer.

14.3.3 For pipes with wall thickness 0.065 in. [1.7 mm] or over, but less than 0.200 in. [5.1 mm], the Rockwell or Vickers hardness test shall be used.

14.3.4 For pipes with wall thickness less than 0.065 in. [1.7 mm], the hardness test shall not be required.

14.3.5 The Brinell test shall be made, at the option of the manufacturer, on the outside of the pipe near the end, on the outside of a specimen cut from the pipe, or on the wall cross section of a specimen cut from the pipe. This test shall be made so that the center of the impression to the edge of the specimen is at least 2.5 times the diameter of the impression.

14.3.6 The Rockwell or Vickers hardness test shall, at the option of the manufacturer, be made on the inside surface, on the wall cross section, or on a flat of the outside surface.

14.3.7 For pipe of Grades P23, P24, P36, P91 Type 1 and Type 2, P92, P93, P115, P122, P128, and P911, Brinell,

Vickers, or Rockwell hardness tests shall be made on one specimen from each lot. For pipe of all other grades, a hardness test is not required.

14.4 *Flattening Test:*

14.4.1 The flattening test of Specification A999/A999M shall be made on a specimen from one end of the pipe with the number of tests as specified in 14.2. Crop ends may be used. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A999/A999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

14.5 *Bend Test:*

14.5.1 For pipe whose diameter exceeds NPS 25 and whose diameter to wall thickness ratio is 7.0 or less shall be subjected to the bend test instead of the flattening test. Other pipe whose diameter equals or exceeds NPS 10 may be given the bend test in place of the flattening test subject to the approval of the purchaser.

14.5.2 The bend test specimens shall be bent at room temperature through 180° without cracking on the outside of the bent portion. The inside diameter of the bend shall be 1 in. [25 mm].

14.5.3 Test specimens for the bend test shall be cut from one end of the pipe with the number of tests as specified in 14.2 and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either ½ by ½ in. [12.5 by 12.5 mm] in section or 1 by ½ in. [25 by 12.5 mm] in section with the corners rounded to a radius not over 1/16 in. [1.6 mm] and need not exceed 6 in. [150 mm] in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe, respectively.

## 15. Certification

15.1 Certification and test reports, as described in Section 25 of Specification A999/A999M, are required.

15.2 In addition to the information required by Specification A999/A999M, the certification shall state whether or not the pipe was hydrostatically tested. If the pipe was nondestructively examined, the certification shall so state and shall show which practice was followed and what reference discontinuities were used. In addition, the test method information as given in Table 9 shall be appended to the specification number and grade shown on the certification.

## 16. Product Marking

16.1 In addition to the marking prescribed in Specification A999/A999M, the marking shall include the length, an additional symbol "S", if the pipe conforms to any of the Supplementary Requirements S1 to S6, the schedule number, if the pipe is ordered to a schedule number, and the heat number or manufacturer's number by which the heat can be identified. Furthermore, the marking designated in Table 9 to indicate the test method(s) shall be included. Marking may be by stenciling, stamping, or rolling. Pipe that has been weld repaired in accordance with 7.6 shall be marked "WR."

16.2 P91 shall be additionally marked with the appropriate Type.

## 17. Government Procurement

17.1 *Scale Free Pipe:*

17.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order, for agencies of the U.S. Government where scale free pipe is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

17.1.2 The requirements of Specification A999/A999M for pipe shall be applicable when pipe is ordered to this specification.

17.1.3 Pipe shall be one of the following grades as specified herein:

| Grade | UNS Designation |
|---|---|
| P11 | K11597 |
| P22 | K21590 |
| P5 | K41545 |

17.1.4 *Part Number:*

**TABLE 9 Test Method Information for Certification and Marking**

| Ultrasonic | Flux Leakage | Eddy Current | Hydrostatic | Marking |
|---|---|---|---|---|
| NO | NO | NO | YES | TEST PRESSURE[A] |
| YES | NO | NO | NO | UT |
| NO | YES | NO | NO | FL |
| NO | NO | YES | NO | EC |
| YES | YES | NO | NO | UT/FL |
| YES | NO | YES | NO | UT/EC |
| NO | NO | NO | NO | NH |
| YES | NO | NO | YES | UT/TEST PRESSURE[A] |
| NO | YES | NO | YES | FL/TEST PRESSURE[A] |
| NO | NO | YES | YES | EC/TEST PRESSURE[A] |

[A]Test pressure is to be in psi [MPa].

17.1.4.1 Pipe shall be ordered to nominal pipe size and schedule specified in ASME B36.10M

*Example:* A335/A335M Pipe P-11 NPS 12 Sch 40

| | |
|---|---|
| Specification Number | ASTM A335/A335M |
| Pipe | P |
| Grade | P-11 |
| NPS | 12 |
| Wall | 0.375 |

17.1.4.2

| | |
|---|---|
| Specification Number | ASTM A335/A335M |
| Tube | T |
| Grade | P-11 |
| Outside Diameter | 0.250 |
| Wall | 0.035 |

17.1.5 *Ordering Information*—Orders for material under this specification shall include the following in addition to the requirements of Section 3:

17.1.5.1 Pipe or tube,

17.1.5.2 Part number,

17.1.5.3 Ultrasonic inspection, if required,

17.1.5.4 If shear wave test is to be conducted in two opposite circumferential directions, and

17.1.5.5 Level of preservation and packing required.

## 18. Keywords

18.1 alloy steel pipe; high temperature service; seamless steel pipe; steel pipe; temperature service applications

## SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

### S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

### S2. Transverse Tension Tests

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 and over. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A999/A999M and satisfactory retest.

### S3. Flattening Test

S3.1 The flattening test of Specification A999/A999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A999/A999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound. The bend test shall be substituted for the flattening test for pipe whose diameter exceeds NPS 25 and whose diameter to wall thickness ratio is 7.0 or less.

### S4. Metal Structure and Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

NOTE S4.1—Pending development of etching methods applicable to the product covered by this specification, it is recommended that the Recommended Practice for a Standard Macro Etch Test for Routine Inspection of Iron and Steel, described in the *Metals Handbook*, Am. Soc. for Metals, 1948 edition, p. 389, be followed.

### S5. Photomicrographs

S5.1 When requested by the purchaser and so stated in the order, the manufacturer shall furnish one photomicrograph at 100 diameters from a specimen of pipe in the as-finished condition for each individual size and wall thickness from each heat, for pipe NPS 3 and over. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, and heat. No photomicrographs for the individual pieces purchased shall be required except as specified in Supplementary Requirement S6. Such photomicrographs are for information only, to show the actual metal structure of the pipe as finished.

### S6. Photomicrographs for Individual Pieces

S6.1 In addition to the photomicrographs required in accordance with Supplementary Requirement S5, the purchaser may specify that photomicrographs shall be furnished from each end of one or more pipes from each lot of pipe NPS 3 and larger in the as-finished condition. The purchaser shall state in the order the number of pipes to be tested from each lot. When photomicrographs are required on each length, the photomicrographs from each lot of pipe in the as-finished condition which may be required under Supplementary Requirement S5

may be omitted. All photo-micrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

## S7. Alternative Heat Treatment—Grade P91 Type 1 and Type 2

S7.1 Grade P91 shall be normalized in accordance with Table 2 and tempered at a temperature, to be specified by the purchaser, less than 1350 °F [730 °C]. It shall be purchaser's responsibility to subsequently temper at 1350–1470 °F [730–800 °C] minimum. All mechanical tests shall be made on material heat treated in accordance with Table 2. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S7" shall be included with the required marking of the pipe.

## S8. Melting Practice—Grades P2 and P12

S8.1 Specific limits, if any, on grain size or deoxidation practice shall be a matter of agreement between the manufacturer and purchaser.

## S9. Minimum Cooling Rate for Grade P91 Type 2

S9.1 For Grade P91 Type 2 material, the heat treatment shall ensure that following austenitizing the rate of cooling from 1650 °F to 900 °F [900 °C to 480 °C] is no slower than 9 °F/min [5 °C/ min].

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A335/A335M – 24a) that may impact the use of this standard. (Approved Oct. 15, 2024.)

*(1)* Added Vickers hardness test information to 14.3.2, 14.3.3, and 14.3.6.

Committee A01 has identified the location of selected changes to this standard since the last issue (A335/A335M – 24) that may impact the use of this standard. (Approved Aug. 15, 2024.)

*(1)* Revised 13.1.

Committee A01 has identified the location of selected changes to this standard since the last issue (A335/A335M – 23) that may impact the use of this standard. (Approved April 1, 2024.)

*(1)* Revised the UNS number for Grade P91 Type 1 and Type 2 in Table 1.

*(2)* Deleted subsection 7.5.1 which specified tools for measurement of wall thickness.

Committee A01 has identified the location of selected changes to this standard since the last issue (A335/A335M – 22) that may impact the use of this standard. (Approved May 1, 2023.)

*(1)* Revised 1.3.

*(2)* Added Supplementary Requirement S9.