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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 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 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 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."

2. Referenced Documents

2.1 *ASTM Standards:*[3]

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

E92 Test Method for Vickers Hardness of Metallic Materials

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

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

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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

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

2.4 *Other Documents:*

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[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 service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

~~[4] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.~~

[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	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 Cb 0.02–0.08 B 0.0010–0.006 N 0.015 max Al 0.030 max W 1.45–1.75 Ni 0.40 max Ti 0.005–0.060 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 Ti 0.06–0.10 N 0.012 max Al 0.02 max 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 Cu 0.50-0.80 Cb 0.015-0.045 V 0.02 max N 0.02 max Al 0.050 max
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 N 0.030–0.070 Ni 0.40 max Al 0.02 max Cb 0.06–0.10 Ti 0.01 max Zr 0.01 max
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 N 0.03–0.07 Ni 0.40 max Al 0.02 max Cb 0.04–0.09 W 1.5–2.00 B 0.001–0.006 Ti 0.01 max Zr 0.01 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 W 1.50–2.50 Cu 0.30–1.70 Cb 0.04–0.10 B 0.0005–0.005 N 0.040–0.100 Ni 0.50 max Al 0.020 max Ti 0.01 max Zr 0.01 max
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 Ni 0.40 max Cb 0.060–0.10 B 0.0003–0.006 N 0.04–0.09 Al 0.02 max W 0.90–1.10 Ti 0.01 max Zr 0.01 max

[A] New designation established in accordance with Practice E527 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.

[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.

SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification[5]
SAE J 1086 Practice for Numbering Metals and Alloys (UNS)[6]

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

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.

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 5.3.

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 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.

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	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1200 [650]
	subcritical anneal	. . .	. . .	1200-1300 [650-705]
P2	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1250 [675]
	subcritical anneal	. . .	. . .	1200-1300 [650-705]
P5	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1250 [675]
P5b	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1250 [675]
P5c	subcritical anneal	. . .	. . .	1325-1375 [715-745]
P9	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1250 [675]
P11	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1200 [650]
P12	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1200 [650]
	subcritical anneal	. . .	. . .	1200-1300 [650-705]
P15	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1200 [650]
P21	full or isothermal anneal	. . .	. . .	. . .
	normalize and temper	. . .	. . .	1250 [675]
P22	full or isothermal anneal	. . .	. . .	. . .
	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	normalize and temper	1900-1975 [1040-1080]	. . .	1350-1470 [730-800][C]
	quench and temper[D]	1900-1975 [1040-1080]	. . .	1350-1470 [730-800]
P92	normalize and temper	1900-1975 [1040-1080]	[E]	1350-1470 [730-800]
P122	normalize and temper	1900-1975 [1040-1080]	. . .	1350-1470 [730-800]
P911	normalize and temper	1900-1975 [1040-1080]	[E]	1365-1435 [740-780]

[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] When mutually agreed upon between the manufacturer and the purchaser, quenching and tempering shall be permitted for thicknesses greater than 3 in. [75 mm].
[E] Accelerated cooling from the normalizing temperature shall be permitted for section thicknesses greater than 3 in. [75 mm].

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 A999/A999M.

~~7.6.1After weld repair, Grades P23, P91, P92, and P122 shall be heat treated at 1350-1470 ºF [730-800 ºC].~~

~~7.6.2After weld repair, Grade P911 shall be heat treated at 1365-1435 ºF [740-780 ºC].~~

~~7.6.3~~

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 shall not exceed 1.0 %.

7.6.2 All repair welds in P92, 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, P92, and P122 shall be heat treated at 1350-1470 ºF [730-800 ºC].

7.6.4 After weld repair, Grade P911 shall be heat treated at 1365-1435 ºF [740-780 ºC].

7.6.5 After weld repair, Grade P24 shall be heat treated at 1350-1420 °F [730-770 °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 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 3.

9.2 Table 4 lists elongation requirements.

9.3 Pipe of Grade P91 shall have a hardness inclusively in the range 190 to 250 HBW/196 to 265 HV [91 HRB to 25 HRC]. Pipe of Grades P24, P92, P122, and P36 shall have a hardness not exceeding 250 HBW/265 HV30 [25 HRC].

9.4 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, P91, P92, P122, and P911	E = 48t + 15.00 [E = 1.87*t* + 15.00]
Transverse, all grades except P23, P91, P92, P122, and P911	E = 32t + 10.00 [E = 1.25*t* + 10.00]
Longitudinal, P23, P24, P91, P92, P122, and P911	E = 32t + 10.00 [E = 1.25*t* + 10.00]
Longitudinal, P36	E = 32t + 5.0 [E = 1.25*t* + 5.0]

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

9.5 For Grade P91, when quenching and tempering has been agreed upon in accordance with Note D in Table 2, 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 6.

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 7. 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.

TABLE 3 Tensile Requirements

	Grade								
	P1, P2	P12	P23	P24	P91	P92, P911 P36 Class 1	P122	P36 Class 2	All Others
Tensile strength, min:									
ksi	55	60	74	85	85	90	90	95.5	60
MPa	380	415	510	585	585	620	620	660	415
Yield strength, min:									
ksi	30	32	58	60	60	64	58	66.5	30
MPa	205	220	400	415	415	440	400	460	205