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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 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*

~~1.1This specification~~

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 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:*~~

~~A450/A450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes~~ ASTM Standards: [3]

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

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

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

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

E 527~~Practice for Numbering Metals and Alloys (UNS)~~[3] Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

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

2.2 *ASME Standard:*

B36.10M Welded and Seamless Wrought Steel Pipe

2.3 *Other Documents:*

SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification[4]

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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* ~~, Vol 01.01.~~volume information, refer to the standard's Document Summary page on the ASTM website.

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

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

***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 0.0005–0.006 N 0.030 max Al 0.030 max W 1.45–1.75
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 0.04 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 0.04 max~~ ~~Cb 0.04–0.09~~ ~~W 1.5–2.00~~ ~~B 0.001–0.006~~
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 0.04 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~~	~~10.00–12.50~~	~~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 0.040 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 0.040 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~~	~~8.50–10.50~~	~~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 0.04 max~~ ~~W 0.90–1.10~~
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

SAE J 1086 Practice for Numbering Metals and Alloys (UNS)[5]

3. Ordering Information

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

~~3.1.1Quantity~~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),

~~3.1.5Size~~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 A 999/A 999M),

3.1.8 Optional requirements (Section 8, ~~11 and~~ 12 and 13 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 A 999/A 999M),

3.1.10 Specification designation, and

3.1.11 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 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*:

~~5.3.1All 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 P15 shall be 1200°F [650°C].~~

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].~~

~~5.3.2Pipe 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.~~

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

~~5.3.4Grades 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.~~

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

~~5.3.6Grade 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.~~

~~5.4Except 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~~

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

[5] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

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]
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]	. . .	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].

~~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 (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 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.

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

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

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 (see 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~~Table 3.

9.2 ~~Table 3~~Table 4 lists elongation requirements.

9.3 Pipe of Grades P91, P92, P122, and ~~P122~~P36 shall have a hardness not exceeding 250 HB/265 HV [25 HRC].

9.4 Table ~~4~~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:

TABLE ~~2~~ 3 Tensile Requirements

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

TABLE ~~3~~ 4 Elongation Requirements

	Elongation Requirements				
	All grades except P23, P36 P91, P92, P122, and P911		~~All other gr~~P23, P91, P92, P122, and~~es~~ P 911		P36
	Longi-tudi-nal	Trans-verse	Longi-tudi-nal	Trans-verse	Longi-tudi-nal
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
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]

[A] Table ~~4~~ 5 gives the calculated minimum values.

TABLE ~~4~~ 5 Calculated Minimum Elongation Values

Wall Thickness		Elongation in 2 in. or 50 mm, min, %			
		All grades except P23, P~~91~~36, P91, P92, P122, and P911		~~All~~P23, P91, P92, ~~other gr~~P122, and~~es~~ P911	P36
in.	mm	Longi-tudinal	Transverse	Longi-tudinal	Longi-tudinal
~~5/16 (0.312)~~	~~8~~	~~30~~	~~20~~	~~20~~	
5/16 (0.312)	8	30	20	20	15
~~9/32 (0.281)~~	~~7.2~~	~~28~~	~~19~~	~~19~~	
9/32 (0.281)	7.2	28	19	19	14
~~1/4 (0.250)~~	~~6.4~~	~~27~~	~~18~~	~~18~~	
1/4 (0.250)	6.4	27	18	18	13
~~7/32 (0.219)~~	~~5.6~~	~~26~~	~~. . .~~	~~17~~	
7/32 (0.219)	5.6	26	. . .	17	12
~~3/16 (0.188)~~	~~4.8~~	~~24~~	~~. . .~~	~~16~~	
3/16 (0.188)	4.8	24	. . .	16	11
~~5/32 (0.156)~~	~~4~~	~~22~~	~~. . .~~	~~15~~	
5/32 (0.156)	4	22	. . .	15	10
~~1/8 (0.125)~~	~~3.2~~	~~21~~	~~. . .~~	~~14~~	
1/8 (0.125)	3.2	21	. . .	14	9
~~3/32 (0.094)~~	~~2.4~~	~~20~~	~~. . .~~	~~13~~	
3/32 (0.094)	2.4	20	. . .	13	8
1/16 (0.062)	1.6	18	. . .	12	7

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]~~
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]~~
Transverse, all grades except P23, P91, P92, P122, and P911	E = 32t + 10.00 [E = 1.25*t* + 10.00]