

ASTM - A335/A335M

Standard Specification for

Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service

This specification 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.

A. Materials and Manufacture :-

- Pipe may be either hot finished or cold drawn with the finishing treatment.

B. Heat Treatment :-

- All pipe shall be reheated for heat treatment and heat treated in accordance with the requirements of Table 1.

Table 1^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 alternative Heat Treatment for Grade P91 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].

C. Chemical Composition :-

□ The steel shall conform to the requirements as to chemical composition prescribed in Table 2.

Table 2

Grade	UNS Designation ^A	C	Mn	P, max	S, max	Si	Cr	Mo	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 0.03 max W 1.45–1.75, Ni 0.40 max Ti 0.005–0.060, Ti/N \geq 3.5 ^C
P24	K30736	0.05–0.10	0.30–0.70	0.02	0.01	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	0.02	0.01	0.20–0.50	8.00–9.50	0.85–1.05	V 0.18–0.25 N 0.03–0.07, 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	0.02	0.01	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	0.02	0.01	0.50 max	10.00–11.50	0.25–0.60	V 0.15–0.30, W 1.50–2.50 Cu 0.3–1.7, Cb 0.04–0.10 B 0.0005–0.005 N 0.04–0.10, 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 0.06–0.10, Zr 0.01 max B 0.0003–0.006 N 0.04–0.09, Al 0.02 max W 0.90–1.10, Ti 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.

D. Tensile Requirements :-

- The tensile properties of the material shall conform to the requirements prescribed in Table 3.
- Table 4 lists elongation requirements.
- 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
 Longitudinal, all grades except P23, P91,
 P92, P122, and P911
 Transverse, all grades except P23, P91,

Equation B
 $E = 48t + 15.00$
 $[E = 1.87 t + 15.00]$
 $E = 32t + 10.00$

P92, P122, and P911
 Longitudinal, P23, P24, P91, P92, P122
 and P911

$$[E = 1.25 t + 10.00]$$

$$E = 32t + 10.00$$

$$[E = 1.25 t + 10.00]$$

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].

Table 3

		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

Table 4

	Elongation Requirements				
	All grades except P23, P36 P91, P92, P122, and P911		P23, P24, P91, P92, P122, and P 911		P36
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal
Elongation in 2 in. or 50 mm, (or 4D), 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 4D (4 times the diameter) is used	22	14	20	13	...
For strip tests a deduction	1.50 ^A	1.00 ^A	1.00 ^A	...	1.00 ^A

^A Table 5 gives the calculated minimum values.

Table 5

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

E. Hardness Requirements :-

The Hardness properties of the material shall conform to the requirements prescribed as follow:

Grade	Hardness
P91	190 to 250 HBW/196 to 265 HV [91 HRB to 25 HRC]
P24, P92, P122, P911, and P36	250 HBW/265 HV30 [25 HRC]
P23	220 HB (HRB 97).

F. Hydrostatic Test :-

1. The requirements for grades other than P91, P92, P911, and P122 are as follow:
 - i. 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 'point F.1.i'.
 - ii. Pipe of all other sizes shall be subjected to the Non-destructive electric test as shown in Section 13, except as provided for in 'point F.1.iii' and 'point F.1.iv'.
 - iii. When specified by the purchaser, pipe of all other sizes shall be furnished without the hydrostatic test and without non-destructive examination. iv. When specified by the purchaser, pipe shall be furnished with both the hydrostatic test and a non-destructive examination having been performed.
2. The requirements for grades P91, P92, P911, and P122 are as follow:
 - i. 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 'G'.
 - ii. Pipe of all other sizes shall be subjected to the Non-destructive electric test, except as provided for in 'point F.2.iii'.
 - iii. When specified by the purchaser, pipe of all other sizes shall be furnished with both the hydrostatic test and a non-destructive examination having been performed.

G. Non-destructive Examination :-

1. Except for Grades P91, P92, P911, and P122, the type of non-destructive examination shall be at the option of the manufacturer, unless otherwise specified in the order.
2. Grades P91, P92, P911, and P122 shall be examined by an examination method in accordance with Practice E213.
3. When specified in the order, pipe of Grades P91, P92, P911, and P122 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.

H. Mechanical Tests :-

1. Transverse or Longitudinal Tension Test.
2. Flattening Test.
3. Hardness Test:
 - i. The Vickers hardness testing shall be made in accordance with Test Method E92. ii. For pipes with wall thickness 0.200 in. [5.1 mm] or over, either the Brinell or Rockwell hardness test shall be used.
 - iii. For pipes with wall thickness 0.065 in. [1.7 mm] or over, but less than 0.200 in. [5.1 mm], the Rockwell hardness test shall be used.
 - iv. For pipes with wall thickness less than 0.065 in. [1.7 mm], the hardness test shall not be required.
4. Bend Test:
 - i. The bend test specimens shall be bent at room temperature through 180° without cracking on the outside of the bent portion.
 - ii. The inside diameter of the bend shall be 1 in. [25 mm].

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].

I. Supplementary Test :-

1. Transverse Tension Tests.
2. Flattening Test.
3. Metal Structure and Etching Tests

Keyword

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