Designation: A333/A333M – 18

Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service and Other Applications with Required Notch Toughness[1]

This standard is issued under the fixed designation A333/A333M; 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.

1. Scope*

1.1 This specification[2] covers nominal (average) wall seamless and welded carbon and alloy steel pipe intended for use at low temperatures and in other applications requiring notch toughness. Several grades of ferritic steel are included as listed in Table 1. Some product sizes may not be available under this specification because heavier wall thicknesses have an adverse effect on impact properties.

1.2 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 1—The dimensionless designator NPS (nominal pipe size) has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.3 *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]

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

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

A671/A671M Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures

E23 Test Methods for Notched Bar Impact Testing of Metallic Materials

E165/E165M Practice for Liquid Penetrant Examination for General Industry

E709 Guide for Magnetic Particle Testing

2.2 *ASME Boiler and Pressure Vessel Code:*[4]

Section VIII

Section IX

3. Ordering Information

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

3.1.1 Quantity (feet, centimetres, or number of lengths),

3.1.2 Name of material (seamless or welded pipe),

3.1.3 Grade (Table 1),

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

3.1.5 Lengths (specific or random) (Section 9), (see the Permissible Variations in Length section of Specification A999/A999M),

3.1.6 End finish (see the Ends section of Specification A999/A999M),

3.1.7 Optional requirements, (see the Heat Analysis requirement in the Chemical Composition section of A999/A999M, the Repair by Welding section, and the section on Nondestructive Test Requirements),

3.1.8 Test report required, (see the Certification section of Specification A999/A999M),

3.1.9 Specification designation, and

3.1.10 Special requirements or exceptions to this specification.

[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-333 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 of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

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

TABLE 1 Chemical Requirements[B]

Element	Composition, %								
	Grade 1	Grade 3	Grade 4	Grade 6	Grade 7	Grade 8	Grade 9	Grade 10	Grade 11
Carbon, max	0.30	0.19	0.12	0.30	0.19	0.13	0.20	0.20	0.10
Manganese	0.40–1.06[A]	0.31–0.64	0.50–1.05	0.29–1.06[A]	0.90 max	0.90 max	0.40–1.06	1.15–1.50	0.60 max
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.035	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.015	0.025
Silicon	...	0.18–0.37	0.08–0.37	0.10 min	0.13–0.32	0.13–0.32	...	0.10–0.35	0.35 max
Nickel	...	3.18–3.82	0.47–0.98	0.40 max	2.03–2.57	8.40–9.60	1.60–2.24	0.25 max	35.0–37.0
Chromium	...	...	0.44–1.01	0.30 max	...	...	...	0.15 max	0.50 max
Copper	...	...	0.40–0.75	0.40 max	...	...	0.75–1.25	0.15 max	...
Aluminum	...	...	0.04–0.30	...	...	...	...	0.06 max	...
Vanadium, max	...	...	...	0.08	...	...	...	0.12	...
Niobium[D], max	...	...	...	0.02[C]	...	...	...	0.05	...
Molybdenum, max	...	...	...	0.12	...	...	...	0.05	0.50 max
Cobalt	...	...	...	...	...	...	...	...	0.50 max

[A] For each reduction of 0.01 % carbon below 0.30 %, an increase of 0.05 % manganese above 1.06 % would be permitted to a maximum of 1.35 % manganese.
[B] Where an ellipsis (...) appears in this table, there is no requirement and analysis for the element need not to be determined or reported.
[C] By agreement between the manufacturer and the purchaser, the limit for niobium may be increased up to 0.05 % on heat analysis and 0.06 % on product analysis.
[D] The terms Niobium (Nb) and Columbium (Cb) are alternate names for the same element.

3.1.11 Supplementary requirements, if any (subsize impact specimens, pipe for hydrofluoric acid alkylation service).

4. Materials and Manufacture

4.1 *Manufacture*—Except as provided in paragraph 4.2, the pipe shall be made by the seamless or welding process with the addition of no filler metal in the welding operation. Grade 4 shall be made by the seamless process.

NOTE 2—For electric-fusion-welded pipe, with filler metal added, fabricated of pressure vessel quality plates, see Specification A671/A671M.

4.2 Grade 11 pipe may be produced by welding with or without the addition of filler metal. The following requirements shall apply for Grade 11 welded with the addition of filler metal.

4.2.1 The joints shall be full-penetration, full fusion double-welded or single-welded butt joints employing fusion welding processes as defined in "Definitions," ASME Boiler and Pressure Vessel Code, Section IX. This specification makes no provision for any difference in weld quality requirements regardless of the weld joint type employed (single or double) in making the weld. Where backing strips are employed, the ring or strip material shall be the same as the plate being joined. Backing rings or strips shall be completely removed after welding, prior to any required radiography, and the exposed weld surface shall be examined visually for conformance to the requirements of 4.2.2. Welds made by procedures employing backing strips or rings which remain in place are prohibited. Welding procedures and welding operators shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

4.2.2 The weld surface on either side of the weld may be flush with the base plate or may have a reasonably uniform crown, not to exceed ⅛ in. [3 mm]. Any weld reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be reasonably smooth and free from irregularities. The deposited metal shall be fused uniformly into the plate surface. No concavity of contour is permitted unless the resulting thickness of weld metal is equal to or greater than the minimum thickness of the adjacent base metal.

4.2.3 *Radiographic Examination*—All welded joints shall be fully radiographed in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest edition, paragraph UW-51.

4.2.3.1 As an alternative, the welded joints may be ultrasonically examined in accordance with Appendix 12 of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

4.2.4 *Repair Welding*—Weld metal defects shall be repaired by removal to sound metal and repair welding if approved by the purchaser.

4.2.4.1 The repair shall be blended smoothly into the surrounding base metal surface and examined by the magnetic particle examination in accordance with Practice E709, or by the liquid penetrant method in accordance with Practice E165/E165M.

4.2.4.2 Each repair weld of a cavity where the cavity, before repair welding, has a depth exceeding the lesser of ⅜ in. [9.5 mm] or 10.5 % of the nominal thickness shall be radiographically examined as required for the original welds.

4.2.5 *Transverse Tension Test*—One test shall be made to represent each lot (Note 3) of finished pipe. The test specimens shall be taken across the welded joint. The tension test results of the welded joints shall conform to the tensile properties for Grade 11 in Table 2.

4.2.5.1 The test specimens shall be taken from the end of the finished pipe. As an alternative, the tension test specimens may be taken from a welded prolongation of the same material as the pipe, which is attached to the end of the pipe and welded as a prolongation of the pipe longitudinal seam.

4.2.5.2 The test specimens shall be in accordance with Section IX, Part QW, paragraph QW-150 of the ASME Boiler and Pressure Vessel Code and shall be one of the types shown in QW-462.1 of that code. The tension test specimen may be flattened cold before final machining to size.

TABLE 2 Tensile Requirements

	Grade 1		Grade 3		Grade 4		Grade 6		Grade 7		Grade 8		Grade 9		Grade 10		Grade 11	
	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa
Tensile strength, min	55 000	380	65 000	450	60 000	415	60 000	415	65 000	450	100 000	690	63 000	435	80 000	550	65 000	450
Yield strength, min	30 000	205	35 000	240	35 000	240	35 000	240	35 000	240	75 000	515	46 000	315	65 000	450	35 000	240
	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	
Elongation in 2 in. or 50 mm, (or 4D), min, %:																		
Basic minimum elongation for walls 5/16 in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section	35	25	30	20	30	16.5	30	16.5	30	22	22	...	28	...	22	...	18[A]	
When standard round 2-in. or 50-mm gage length or proportionally smaller size test specimen with the gage length equal to 4D (4 times the diameter) is used	28	20	22	14	22	12	22	12	22	14	16	...	...	...	16	...	...	
For strip tests, a deduction for each 1/32 in. [0.8 mm] decrease in wall thickness below 5/16 in. [8 mm] from the basic minimum elongation of the following percentage	1.75[B]	1.25[B]	1.50[B]	1.00[B]	1.50[B]	1.00[B]	1.50[B]	1.00[B]	1.50[B]	1.00[B]	1.25[B]	...	1.50[B]	...	1.25[B]	...	...	

Wall Thickness		Elongation in 2 in. or 50 mm, min, %[C]															
		Grade 1		Grade 3		Grade 4		Grade 6		Grade 7		Grade 8		Grade 9		Grade 10	
in.	mm	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse
5/16 (0.312)	8	35	25	30	20	30	16	30	16	30	22	22	...	28	...	22	...
9/32 (0.281)	7.2	33	24	28	19	28	15	28	15	28	21	21	...	26	...	21	...
1/4 (0.250)	6.4	32	23	27	18	27	15	27	15	27	20	20	...	25	...	20	...
7/32 (0.219)	5.6	30	...	26	...	26	...	26	...	26	...	18	...	24	...	18	...
3/16 (0.188)	4.8	28	...	24	...	24	...	24	...	24	...	17	...	22	...	17	...
5/32 (0.156)	4	26	...	22	...	22	...	22	...	22	...	16	...	20	...	16	...
1/8 (0.125)	3.2	25	...	21	...	21	...	21	...	21	...	15	...	19	...	15	...
3/32 (0.094)	2.4	23	...	20	...	20	...	20	...	20	...	13	...	18	...	13	...
1/16 (0.062)	1.6	21	...	18	...	18	...	18	...	18	...	12	...	16	...	12	...

[A] Elongation of Grade 11 is for all walls and small sizes tested in full section.
[B] The following table gives the calculated minimum values.
[C] Calculated elongation requirements shall be rounded to the nearest whole number.

Note—The preceding table gives the computed minimum elongation values for each 1/32-in. [0.80-mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equation:

Grade	Direction of Test	Equation
1	Longitudinal	$E = 56\,t + 17.50$ [$E = 2.19\,t + 17.50$]
	Transverse	$E = 40\,t + 12.50$ [$E = 1.56\,t + 12.50$]
3	Longitudinal	$E = 48\,t + 15.00$ [$E = 1.87\,t + 15.00$]
	Transverse	$E = 32\,t + 10.00$ [$E = 1.25\,t + 10.00$]
4	Longitudinal	$E = 48\,t + 15.00$ [$E = 1.87\,t + 15.00$]
	Transverse	$E = 32\,t + 6.50$ [$E = 1.25\,t + 6.50$]
6	Longitudinal	$E = 48\,t + 15.00$ [$E = 1.87\,t + 15.00$]
	Transverse	$E = 32\,t + 6.50$ [$E = 1.25\,t + 6.50$]
7	Longitudinal	$E = 48\,t + 15.00$ [$E = 1.87\,t + 15.00$]
	Transverse	$E = 32\,t + 11.00$ [$E = 1.25\,t + 11.00$]
8 and 10	Longitudinal	$E = 40\,t + 9.50$ [$E = 1.56\,t + 9.50$]
9	Longitudinal	$E = 48\,t + 13.00$ [$E = 1.87\,t + 13.00$]

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

4.2.6 *Transverse Guided-Bend Weld Test*—One transverse guided bend test (two specimens) shall be made to represent each lot (Note 3) of finished pipe.

4.2.6.1 The two bend test specimens shall be taken from the weld at the end of the finished pipe. As an alternative, by agreement between the purchaser and the manufacturer, the test