



Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service and Other Applications with Required Notch Toughness¹

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 specification² 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.”

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 Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures](#)
- [E23 Test Methods for Notched Bar Impact Testing of Metallic Materials](#)

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.

- [E165 Practice for Liquid Penetrant Examination for General Industry](#)
- [E709 Guide for Magnetic Particle Testing](#)
- [2.2 ASME Boiler and Pressure Vessel Code: 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.
- 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

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 | ... | |
| Columbium, 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 columbium may be increased up to 0.05 % on heat analysis and 0.06 % on product analysis.

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.

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 1/8 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.

4.2.4.2 Each repair weld of a cavity where the cavity, before repair welding, has a depth exceeding the lesser of 3/8 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.

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 specimens may be taken from a test plate of the same material

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 | Trans- verse |
| 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 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 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 | 35 | 25 | 30 | 20 | 30 | 16.5 | 30 | 16.5 | 30 | 22 | 22 | ... | 28 | ... | 22 | ... | 18 ^A | |
| | 28 | 20 | 22 | 14 | 22 | 12 | 22 | 12 | 22 | 14 | 16 | ... | ... | ... | 16 | ... | ... | |
| | 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 | ... |
| 3/32 (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 | $E = 56 t + 17.50$ [$E = 2.19t + 17.50$] |
| | Transverse | $E = 40 t + 12.50$ [$E = 1.56t + 12.50$] |
| 3 | Longitudinal | $E = 48 t + 15.00$ [$E = 1.87t + 15.00$] |
| | Transverse | $E = 32 t + 10.00$ [$E = 1.25t + 10.00$] |
| 4 | Longitudinal | $E = 48 t + 15.00$ [$E = 1.87t + 15.00$] |
| | Transverse | $E = 32 t + 6.50$ [$E = 1.25 t + 6.50$] |
| 6 | Longitudinal | $E = 48 t + 15.00$ [$E = 1.87t + 15.00$] |
| | Transverse | $E = 32 t + 6.50$ [$E = 1.25 t + 6.50$] |
| 7 | Longitudinal | $E = 48 t + 15.00$ [$E = 1.87t + 15.00$] |
| | Transverse | $E = 32 t + 11.00$ [$E = 1.25t + 11.00$] |
| 8 and 10 | Longitudinal | $E = 40 t + 9.50$ [$E = 1.56t + 9.50$] |
| | 9 | Longitudinal |

where:

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

as the pipe, the test plate being attached to the end of the pipe and welded as a prolongation of the pipe longitudinal seam.

4.2.6.2 The bend test shall be in accordance with QW-160 of Section IX of the ASME Boiler and Pressure Vessel Code.

4.2.7 Charpy V-notch Impact Tests—Impact tests on welded joints shall include tests on weld metal and heat affected zones and shall meet the same requirements as the base metal. (See Tables 3 and 4).

TABLE 3 Impact Requirements for Grades 1, 3, 4, 6, 7, 9, 10, and 11

| Size of Specimen, mm | Minimum Average Notched Bar Impact Value of Each Set of Three Specimens ^A | | Minimum Notched Bar Impact Value of One Specimen Only of a Set ^A | |
|----------------------|--|----|---|----|
| | ft-lbf | J | ft-lbf | J |
| 10 by 10 | 13 | 18 | 10 | 14 |
| 10 by 7.5 | 10 | 14 | 8 | 11 |
| 10 by 6.67 | 9 | 12 | 7 | 9 |
| 10 by 5 | 7 | 9 | 5 | 7 |
| 10 by 3.33 | 5 | 7 | 3 | 4 |
| 10 by 2.5 | 4 | 5 | 3 | 4 |

^A Straight line interpolation for intermediate values is permitted.

TABLE 4 Impact Temperature

| Grade | Minimum Impact Test Temperature | |
|-------|---------------------------------|------|
| | °F | °C |
| 1 | -50 | -45 |
| 3 | -150 | -100 |
| 4 | -150 | -100 |
| 6 | -50 | -45 |
| 7 | -100 | -75 |
| 8 | -320 | -195 |
| 9 | -100 | -75 |
| 10 | -75 | -60 |
| 11 | -320 | -195 |

4.2.7.1 Each set of weld metal impact test specimens shall be taken across the weld with the notch in the weld metal. Each test specimen shall be oriented so that the notch is normal to the surface of the material and one face of the specimen shall be within 1/16 in. [1.5 mm] of the surface of the material.

4.2.7.2 Each set of heat affected zone impact test specimens shall be taken across the weld and of sufficient length to locate, after etching, the notch in the heat affected zone. The notch shall be cut approximately normal to the surface of the material in such a manner as to include as much heat affected zone material as possible in the resulting fracture.

NOTE 3—The term “lot” applies to all pipe (may include more than one heat of steel) within a 3/16 in. [4.7 mm] range of thickness and welded to the weld procedure, and when heat treated, done to the same heat-treating procedure and in the same furnace. The maximum lot size shall be 200 linear ft [60 m] of pipe.

4.3 Heat Treatment:

4.3.1 All seamless and welded pipe, other than Grades 8 and 11, shall be treated to control their microstructure in accordance with one of the following methods:

4.3.1.1 Normalize by heating to a uniform temperature of not less than 1500 °F [815 °C] and cool in air or in the cooling chamber of an atmosphere controlled furnace.

4.3.1.2 Normalize as in 4.3.1.1, and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

4.3.1.3 For the seamless process only, reheat and control hot working and the temperature of the hot-finishing operation to a finishing temperature range from 1550 to 1750 °F [845 to 945 °C] and cool in air or in a controlled atmosphere furnace from an initial temperature of not less than 1550 °F [845 °C].

4.3.1.4 Treat as in 4.3.1.3 and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

4.3.1.5 Seamless pipe of Grades 1, 6, and 10 may be heat treated by heating to a uniform temperature of not less than 1500 °F [815 °C], followed by quenching in liquid and reheating to a suitable tempering temperature, in place of any of the other heat treatments provided for in 4.3.1.

4.3.2 Grade 8 pipe shall be heat treated by the manufacturer by either of the following methods:

4.3.2.1 *Quenched and Tempered*—Heat to a uniform temperature of 1475 ± 25 °F [800 ± 15 °C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; quench by immersion in circulating water. Reheat until the pipe attains a uniform temperature within the range from 1050 to 1125 °F [565 to 605 °C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air or water quench at a rate no less than 300 °F [165 °C]/h.

4.3.2.2 *Double Normalized and Tempered*—Heat to a uniform temperature of 1650 ± 25 °F [900 ± 15 °C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat until the pipe attains a uniform temperature of 1450 ± 25 °F [790 ± 15 °C]; hold at this temperature for a minimum time in the ratio of 1 h/in. [2 min/mm] of thickness, but in no case less than 15 min; cool in air. Reheat to a uniform temperature within the range from 1050 to 1125 °F [565 to 605 °C]; hold at this temperature for a minimum time of 1 h/in. [2 min/mm] of thickness but in no case less than 15 min; cool in air or water quench at a rate not less than 300 °F [165 °C]/h.

4.3.3 Whether to anneal Grade 11 pipe is per agreement between purchaser and supplier. When Grade 11 pipe is annealed, it shall be normalized in the range of 1400 to 1600 °F [760 to 870 °C].

4.3.4 Material from which test specimens are obtained shall be in the same condition of heat treatment as the pipe furnished. Material from which specimens are to be taken shall be heat treated prior to preparation of the specimens.

4.3.5 When specified in the order the test specimens shall be taken from full thickness test pieces which have been stress relieved after having been removed from the heat-treated pipe. The test pieces shall be gradually and uniformly heated to the prescribed temperature, held at that temperature for a period of time in accordance with Table 5, and then furnace cooled at a temperature not exceeding 600 °F [315 °C]. Grade 8 shall be

TABLE 5 Stress Relieving of Test Pieces

| Metal Temperature ^{A,B} | | | | Minimum Holding Time, h/in. [min/mm] of Thickness |
|----------------------------------|-----|----------------------|-----|---|
| Grades 1, 3, 6, 7, and 10 | | Grade 4 ^C | | |
| °F | °C | °F | °C | |
| 1100 | 600 | 1150 | 620 | 1 [2.4] |
| 1050 | 565 | 1100 | 600 | 2 [4.7] |
| 1000 | 540 | 1050 | 565 | 3 [7.1] |

^A For intermediate temperatures, the holding time shall be determined by straight-line interpolation.

^B Grade 8 shall be stress relieved at 1025 to 1085 °F, [550 to 585 °C], held for a minimum time of 2 h for thickness up to 1.0 in. [25.4 mm], plus a minimum of 1 h for each additional inch [25.4 mm] of thickness and cooled at a minimum rate of 300 °F [165 °C]/h in air or water to a temperature not exceeding 600 °F [315 °C].

^C Unless otherwise specified, Grade 4 shall be stress relieved at 1150 °F [620 °C].

cooled at a minimum rate of 300 °F [165 °C]/h in air or water to a temperature not exceeding 600 °F [315 °C].

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition prescribed in **Table 1**.

5.2 When Grades 1, 6, or 10 are ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in **Table 1** is not permitted. However, the addition of elements required for the deoxidation of the steel is permitted.

6. Product Analysis

6.1 At the request of the purchaser, an analysis of one billet or two samples of flat-rolled stock from each heat or of two pipes from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following:

| | |
|----------------|-------------------------|
| NPS Designator | Length of Pipe in Lot |
| Under 2 | 400 or fraction thereof |
| 2 to 6 | 200 or fraction thereof |
| Over 6 | 100 or fraction thereof |

6.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified.

6.3 If the analysis of one of the tests specified in **6.1** does not conform to the requirements specified, 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.

7. Tensile Requirements

7.1 The material shall conform to the requirements as to tensile properties prescribed in **Table 2**.

8. Impact Requirements

8.1 For Grades 1, 3, 4, 6, 7, 9, 10, and 11, the notched-bar impact properties of each set of three impact specimens, including specimens for the welded joint in welded pipe with wall thicknesses of 0.120 in. [3 mm] and larger, when tested at temperatures in conformance with **14.1** shall be not less than the values prescribed in **Table 3**.

8.1.1 If the impact value of one specimen is below the minimum value, or the impact values of two specimens are less than the minimum average value but not below the minimum value permitted on a single specimen, a retest shall be allowed. The retest shall consist of breaking three additional specimens and each specimen must equal or exceed the required average value. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedures, a retest will be allowed.

8.2 For Grade 8 each of the notched bar impact specimens shall display a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm].

8.2.1 When the average lateral expansion value for the three impact specimens equals or exceeds 0.015 in. [0.38 mm] and the value for one specimen is below 0.015 in. [0.38 mm] but not below 0.010 in. [0.25 mm], a retest of three additional

specimens may be made. The lateral expansion of each of the retest specimens must equal or exceed 0.015 in. [0.38 mm].

8.2.2 Lateral expansion values shall be determined by the procedure in Test Methods and Definitions **A370**.

8.2.3 The values of absorbed energy in foot-pounds and the fracture appearance in percentage shear shall be recorded for information. A record of these values shall be retained for a period of at least 2 years.

9. Lengths

9.1 If definite lengths are not required, pipe may be ordered either in single random lengths of 16 to 22 ft (**Note 4**) with maximum 5 % of the lengths between 12 and 16 ft (**Note 4**), or in double random lengths with a minimum average of 35 ft (**Note 4**) and an absolute minimum length of 22 ft (**Note 4**) with maximum 5 % of the lengths between 16 and 22 ft (**Note 4**).

NOTE 4—This value(s) applies when the inch-pound designation of this specification is the basis of purchase. When the "M" designation of this specification is the basis of purchase, the corresponding metric value(s) shall be agreed upon between the manufacturer and purchaser.

10. Workmanship, Finish, and Appearance

10.1 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 **10.2**.

10.2 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:

10.2.1 The defect may be removed by grinding provided that the remaining wall thickness is within specified limits.

10.2.2 Repaired in accordance with the repair welding provisions of **10.5**.

10.2.3 The section of pipe containing the defect may be cut off within the limits of requirements on length.

10.2.4 The defective pipe may be rejected.

10.3 To provide a workmanlike finish and basis for evaluating conformance with **10.2**, the pipe manufacturer shall remove by grinding the following:

10.3.1 Mechanical marks, abrasions and pits, any of which imperfections are deeper than ¼ in. [1.6 mm], and

10.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with **10.1** to be deeper than 5 % of the nominal wall thickness.

10.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under **10.2** 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.

10.5 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.

10.5.1 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.

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

10.7 The finished pipe shall be reasonably straight.

11. General Requirements

11.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification **A999/A999M** unless otherwise provided herein.

12. Mechanical Testing

12.1 *Sampling*—For mechanical testing, the term “lot” applies to all pipe of the same nominal size and wall thickness (or schedule) that is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace. If the final heat treatment is in a batch-type furnace, the lot shall include only those pipes that are heat treated in the same furnace charge.

12.2 *Transverse or Longitudinal Tensile Test and Flattening Test*—For material heat treated in a batch-type furnace, tests shall be made on 5 % of the pipe from each lot. If 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 pipes.

12.3 *Impact Test*—One notched bar impact test, consisting of breaking three specimens, shall be made from each heat represented in a heat-treatment load on specimens taken from the finished pipe. This test shall represent only pipe from the same heat and the same heat-treatment load, the wall thicknesses of which do not exceed by more than ¼ in. [6.3 mm] the wall thicknesses of the pipe from which the test specimens are taken. If heat treatment is performed in continuous or batch-type furnaces controlled within a 50 °F [30 °C] range and equipped with recording pyrometers so that complete records of heat treatment are available, then one test from each heat in a continuous run only shall be required instead of one test from each heat in each heat-treatment load.

12.4 *Impact Tests (Welded Pipe)*—On welded pipe, additional impact tests of the same number as required in **12.3** shall be made to test the weld.

12.5 Specimens showing defects while being machined or prior to testing may be discarded and replacements shall be considered as original specimens.

12.6 Results obtained from these tests shall be reported to the purchaser or his representative.

13. Specimens for Impact Test

13.1 Notched bar impact specimens shall be of the simple beam, Charpy-type, in accordance with Test Methods **E23**,

Type A with a V notch. Standard specimens 10 by 10 mm in cross section shall be used unless the material to be tested is of insufficient thickness, in which case the largest obtainable subsize specimens shall be used. Charpy specimens of width along the notch larger than 0.394 in. [10 mm] or smaller than 0.099 in. [2.5 mm] are not provided for in this specification.

13.2 Test specimens shall be obtained so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the pipe while the axis of the notch shall be perpendicular to the surface. On wall thicknesses of 1 in. [25 mm] or less, the specimens shall be obtained with their axial plane located at the midpoint; on wall thicknesses over 1 in. [25 mm], the specimens shall be obtained with their axial plane located ½ in. [12.5 mm] from the outer surface.

13.3 When testing welds the specimen shall be, whenever diameter and thickness permit, transverse to the longitudinal axis of the pipe with the notch of the specimen in the welded joint and perpendicular to the surface. When diameter and thickness do not permit obtaining transverse specimens, longitudinal specimens in accordance with **13.2** shall be obtained; the bottom of the notch shall be located at the weld joint.

14. Impact Test

14.1 Except when the size of the finished pipe is insufficient to permit obtaining subsize impact specimens, all material furnished to this specification and marked in accordance with Section **16** shall be tested for impact resistance at the minimum temperature for the respective grades as shown in **Table 4**.

14.1.1 Special impact tests on individual lots of material may be made at other temperatures as agreed upon between the manufacturer and the purchaser.

14.1.2 When subsize Charpy impact specimens are used and the width along the notch is less than 80 % of the actual wall thickness of the original material, the specified Charpy impact test temperature for Grades 1, 3, 4, 6, 7, 9, 10, and 11 shall be lower than the minimum temperature shown in **Table 4** for the respective grade. Under these circumstances the temperature reduction values shall be by an amount equal to the difference (as shown in **Table 6**) between the temperature reduction corresponding to the actual material thickness and the temperature reduction corresponding to the Charpy specimen width

TABLE 6 Impact Temperature Reduction

| Specimen Width Along Notch or Actual Material Thickness | | Temperature Reduction, Degrees Colder ^A | |
|---|--------------------|--|----|
| in. | mm | °F | °C |
| 0.394 | 10 (standard size) | 0 | 0 |
| 0.354 | 9 | 0 | 0 |
| 0.315 | 8 | 0 | 0 |
| 0.295 | 7.5 (¾ std. size) | 5 | 3 |
| 0.276 | 7 | 8 | 4 |
| 0.262 | 6.67 (⅔ std. size) | 10 | 5 |
| 0.236 | 6 | 15 | 8 |
| 0.197 | 5 (½ std. size) | 20 | 11 |
| 0.158 | 4 | 30 | 17 |
| 0.131 | 3.33 (⅓ std. size) | 35 | 19 |
| 0.118 | 3 | 40 | 22 |
| 0.099 | 2.5 (¼ std. size) | 50 | 28 |

^A Straight line interpolation for intermediate values is permitted.

actually tested. **Appendix X1** shows some examples of how the temperature reductions are determined.

14.2 The notched bar impact test shall be made in accordance with the procedure for the simple beam, Charpy-type test of Test Methods **E23**.

14.3 Impact tests specified for temperatures lower than 70 °F [20 °C] should be made with the following precautions. The impact test specimens as well as the handling tongs shall be cooled a sufficient time in a suitable container so that both reach the desired temperature. The temperature shall be measured with thermocouples, thermometers, or any other suitable devices and shall be controlled within 3 °F [2 °C]. The specimens shall be quickly transferred from the cooling device to the anvil of the Charpy impact testing machine and broken with a time lapse of not more than 5 s.

15. Hydrostatic or Nondestructive Electric Test

15.1 Each pipe shall be subjected to the nondestructive electric test or the hydrostatic test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

15.2 The hydrostatic test shall be in accordance with Specification **A999/A999M**.

15.3 *Nondestructive Electric Test*—Nondestructive electric tests shall be in accordance with Specification **A999/A999M**, with the following addition:

15.3.1 If the test signals were produced by visual imperfections (listed in **15.3.2**), the pipe may be accepted based on visual examination, provided the imperfection is less than 0.004 in. (0.1 mm) or 12½ % of the specified wall thickness (whichever is greater).

15.3.2 *Visual Imperfections*:

15.3.2.1 Scratches,

15.3.2.2 Surface roughness,

15.3.2.3 Dings,

15.3.2.4 Straightener marks,

15.3.2.5 Cutting chips,

15.3.2.6 Steel die stamps,

15.3.2.7 Stop marks, or

15.3.2.8 Pipe reducer ripple.

16. Product Marking

16.1 Except as modified in **16.1.1**, in addition to the marking prescribed in Specification **A999/A999M**, the marking shall include whether hot finished, cold drawn, seamless or welded, the schedule number and the letters “LT” followed by the temperature at which the impact tests were made, except when a lower test temperature is required because of reduced specimen size, in which case, the higher impact test temperature applicable to a full-size specimen should be marked.

16.1.1 When the size of the finished pipe is insufficient to obtain subsize impact specimens, the marking shall not include the letters “LT” followed by an indicated test temperature unless Supplementary Requirement S1 is specified.

16.1.2 When the pipe is furnished in the quenched and tempered condition, the marking shall include the letters “QT,” and the heat treatment condition shall be reported to the purchaser or his representative.

17. Keywords

17.1 low; low temperature service; seamless steel pipe; stainless steel pipe; steel pipe; temperature service applications

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the contract or order.

S1. Subsize Impact Specimens

S1.1 When the size of the finished pipe is insufficient to permit obtaining subsize impact specimens, testing shall be a matter of agreement between the manufacturer and the purchaser.

S2. Requirements for Pipe for Hydrofluoric Acid Alkylation Service

S2.1 The carbon equivalent (CE), based on heat analysis, shall not exceed 0.43 % if the specified wall thickness is equal to or less than 1 in. [25.4 mm] or 0.45 % if the specified wall thickness is greater than 1 in. [25.4 mm].

S2.2 The carbon equivalent shall be determined using the following formula:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S2.3 Based upon heat analysis in mass percent, the vanadium content shall not exceed 0.02 %, the niobium content shall not exceed 0.02 % and the sum of the vanadium and niobium contents shall not exceed 0.03 %.

S2.4 Based upon heat analysis in mass percent, the sum of the nickel and copper contents shall not exceed 0.15 %.

S2.5 Based upon heat analysis in mass percent, the carbon content shall not be less than 0.18 %.

S2.6 Welding consumables for repair welds shall be of low hydrogen type. E60XX electrodes shall not be used, and the resultant weld chemistry shall meet the chemical composition requirements specified for the pipe.

S2.7 The designation “HF” shall be stamped or marked on each pipe to signify that the pipe complies with this supplementary requirement.

APPENDIX**(Nonmandatory Information)****X1. DETERMINATION OF TEMPERATURE REDUCTIONS**

X1.1 Under the circumstances stated in 14.1.2, the impact test temperatures specified in Table 4 must be lowered. The following examples are offered to describe the application of the provisions of 14.1.2.

X1.1.1 When subsize specimens are used (see 10.1) and the width along the notch of the subsize specimen is 80 % or greater of the actual wall thickness of the original material, the provisions of 14.1.2 do not apply.

X1.1.1.1 For example, if the actual wall thickness of pipe was 0.200 in. [5.0 mm] and the width along the notch of the largest subsize specimen obtainable is 0.160 in. [4 mm] or greater, no reduction in test temperature is required.

X1.1.2 When the width along the subsize specimen notch is less than 80 % of the actual wall thickness of the pipe, the

required reduction in test temperature is computed by taking the difference between the temperature reduction values shown in Table 6 for the actual pipe thickness and the specimen width used.

X1.1.2.1 For example, if the pipe were 0.262 in. [6.67 mm] thick and the width along the Charpy specimen notch was 3.33 mm (1/3 standard size), the test temperature would have to be lowered by 25 °F [14 °C]. That is, the temperature reduction corresponding to the subsize specimen is 35 °F [19 °C]; the temperature reduction corresponding to the actual pipe thickness is 10 °F [5 °C]; the difference between these two values is the required reduction in test temperature.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A333/A333M–15, that may impact the use of this specification. (Approved March 1, 2016)

- (1) Transfer of Footnote A of Table 1 to the requirements for Manganese for Grade 1 and Grade 6.
- (2) Transfer of Footnote B to the title of Table 1 and rewording of Footnote B.
- (3) Introduction of Footnote C in Table 1 for Grade 6.

Committee A01 has identified the location of selected changes to this specification since the last issue, A333/A333M–13, that may impact the use of this specification. (Approved November 1, 2015)

- (1) Removed former Supplementary Requirement S2.1 and renumbered remaining sections accordingly.

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