

SPECIFICATION FOR SEAMLESS AND WELDED CARBON AND ALLOY-STEEL TUBES FOR LOW-TEMPERATURE SERVICE



SA-334/SA-334M



(Identical with ASTM Specification A334/A334M-04a(2016).)

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1. Scope

1.1 This specification covers several grades of minimum-wall-thickness, seamless and welded, carbon and alloy-steel tubes intended for use at low temperatures. Some product sizes may not be available under this specification because heavier wall thicknesses have an adverse affect on low-temperature impact properties.

1.2 Supplementary Requirement S1 of an optional nature is provided. This shall apply only when specified by the purchaser.

NOTE 1 — For tubing smaller than $\frac{1}{2}$ in. [12.7 mm] in outside diameter, the elongation values given for strip specimens in Table 1 shall apply. Mechanical property requirements do not apply to tubing smaller than $\frac{1}{8}$ in. [3.2 mm] in outside diameter and with a wall thickness under 0.015 in. [0.4 mm].

1.3 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.

2. Referenced Documents

2.1 ASTM Standards:

- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
- A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials

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 or welded tubes),
- 3.1.3** Grade (Table 1),
- 3.1.4** Size (outside diameter and minimum wall thickness),
- 3.1.5** Length (specific or random),
- 3.1.6** Optional requirements (other temperatures, Section 14; hydrostatic or electric test, Section 16),
- 3.1.7** Test report required, (Certification Section of Specification A 1016/A 1016M),
- 3.1.8** Specification designation, and
- 3.1.9** Special requirements and any supplementary requirements selected.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 1016/A 1016M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 The tubes shall be made by the seamless or automatic welding process with no addition of filler metal in the welding operation.

6. Heat Treatment

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

6.1.1 Normalize by heating to a uniform temperature of not less than 1550°F [845°C] and cool in air or in the cooling chamber of an atmosphere controlled furnace.

6.1.2 Normalize as in 10.1.1, and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

6.1.3 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 955°C] and cool in a controlled atmosphere furnace from an initial temperature of not less than 1550°F [845°C].

6.1.4 Treat as in 6.1.3 and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

6.2 Grade 8 tubes shall be heat treated by the manufacturer by either of the following methods.

6.2.1 *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.

6.2.2 *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.

6.3 Material from which impact specimens are obtained shall be in the same condition of heat treatment as the finished tubes.

6.4 Whether to anneal Grade 11 tubes is per agreement between purchaser and supplier. When Grade 11 tubes are annealed they shall be normalized in the range of 1400 to 1600°F [760 to 870°C].

7. Chemical Composition

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

7.2 When Grades 1 or 6 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.

8. Product Analysis

8.1 An analysis of either one billet or one length of flat-rolled stock or one tube shall be made for each heat. The chemical composition thus determined shall conform to the requirements specified.

8.2 If the original test for product analysis fails, retests of two additional billets, lengths of flat-rolled stock, or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of the specification; otherwise all remaining material in the heat or lot shall be rejected or, at the option of the manufacturer, each billet, length of flat-rolled stock, or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock, or tubes which do not meet the requirements of the specification shall be rejected.

9. Sampling

9.1 For flattening, flare, and flange requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and from the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, the number of tubes of the same size and from the same heat in a lot shall be determined from the size of the tubes as prescribed in Table 2.

9.2 For tensile and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness which are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, a lot shall include all tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat and furnace speed.

10. Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties prescribed in Table 3.

11. Hardness Requirements

11.1 The tubes shall have a hardness number not exceeding those prescribed in Table 4.

12. Impact Requirements

12.1 For Grades 1, 3, 6, 7 and 9, 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 5. The impact test is not required for Grade 11.

12.1.1 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.

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

12.2.1 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].

12.2.2 Lateral expansion values shall be determined in accordance with Test Methods and Definitions A 370.

12.2.3 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.

13. Mechanical Tests

13.1 Tension Test — One tension test shall be made on a specimen for lots of not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes.

13.2 Flattening Test — One flattening test shall be made on specimens from each end of one finished tube of each lot but not the one used for the flare or flange test.

13.3 Flare Test (Seamless Tubes) — One flare test shall be made on specimens from each end of one finished tube of each lot, but not the one used for the flattening test.

13.4 Flange Test (Welded Tubes) — One flange test shall be made on specimens from each end of one finished tube of each lot, but not the one used for the flattening test.

13.5 Reverse Flattening Test — For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft [460 m] of finished tubing.

13.6 Hardness Test — Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot.

13.7 Impact Tests — 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 tube. This test shall represent only tubes from the same heat, which have wall thicknesses not exceeding by more than $\frac{1}{4}$ in. [6.3 mm] the wall thicknesses of the tube 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 which yield complete heat-treatment records, 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.

13.8 Impact Tests (Welded Tubes) — On welded tube, additional impact tests of the same number as required in 13.7 shall be made to test the weld.

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

14. Specimens for Impact Test

14.1 Notched-bar impact specimens shall be of the simple beam, Charpy-type, in accordance with Test Methods E 23, 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.

14.2 Test specimens shall be obtained so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the tube 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 $\frac{1}{2}$ in. [12.5 mm] from the outer surface.

14.3 When testing welds the specimen shall be, whenever diameter and thickness permits, transverse to the longitudinal axis of the tube with the notch of the specimen

in the welded joint and perpendicular to the surface. When diameter and thickness does not permit obtaining transverse specimens, longitudinal specimens in accordance with 14.2 shall be obtained. The bottom of the notch shall be located at the weld joint.

15. Impact Test

15.1 Except when the size of the finished tube is insufficient to permit obtaining subsize impact specimens, all material furnished under this specification and marked in accordance with Section 17 shall be tested for impact resistance at the temperature for the respective grades as prescribed in Table 6.

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

15.2 The notched-bar impact test shall be made in accordance with the procedure for the simple beam, Charpy-type of test of Test Methods E 23.

15.3 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.

15.4 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, 6, 7, and 9 shall be lower than the minimum temperature shown in Table 6 for the respective grade. Under these circumstances the temperature reduction values shall be by an amount equal to the difference (as shown in Table 7) between the temperature reduction corresponding to the actual material thickness and the temperature reduction corresponding to Charpy specimen width actually tested. The appendix shows some examples of how the temperature reductions are determined.

16. Hydrostatic or Nondestructive Electric Test

16.1 Each tube shall be subjected to the nondestructive electric test or the hydrostatic test in accordance with Specification A 1016/A 1016M. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

17. Product Marking

17.1 Except as modified in 16.1.1, in addition to the marking prescribed in Specification A 1016/A 1016M, the marking shall include whether hot-finished, cold-drawn, seamless, or welded, 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.

17.1.1 When the size of the finished tube 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.

TABLE 1
CHEMICAL REQUIREMENTS

Element	Composition, %						
	Grade 1 [Note (1)]	Grade 3	Grade 6 [Note (1)]	Grade 7	Grade 8	Grade 9	Grade 11
Carbon, max	0.30	0.19	0.30	0.19	0.13	0.20	0.10
Manganese	0.40–1.06	0.31–0.64	0.29–1.06	0.90 max	0.90 max	0.40–1.06	0.60 max
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Silicon	...	0.18–0.37	0.10 min	0.13–0.32	0.13–0.32	...	0.35 max
Nickel	...	3.18–3.82	...	2.03–2.57	8.40–9.60	1.60–2.24	35.0–37.0
Chromium	...	...	...	...	...	...	0.50 max
Copper	...	...	...	...	...	0.75–1.25	...
Cobalt	...	...	...	...	...	...	0.50 max
Molybdenum	...	...	...	...	...	...	0.50 max

NOTE:

(1) For each reduction of 0.01% carbon below 0.30%, an increase of 0.05% manganese above 1.06% will be permitted to a maximum of 1.35% manganese.

TABLE 2
HEAT-TREATMENT LOT

Size of Tube	Size of Lot
2 in. [50.8 mm] and over in outside diameter and 0.200 in. [5.1 mm] and over in wall thickness	not more than 50 tubes
Under 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter, or over 1 in. [25.4 mm] in outside diameter and under 0.200 in. [5.1 mm] in thickness	not more than 75 tubes
1 in. [25.4 mm] or under in outside diameter	not more than 125 tubes

TABLE 3
TENSILE REQUIREMENTS

	Grade 1		Grade 3		Grade 6		Grade 7		Grade 8		Grade 9		Grade 11	
	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa	ksi	MPa
Tensile Strength, min	55	380	65	450	60	415	65	450	100	690	63	435	65	450
Yield Strength, min	30	205	35	240	35	240	35	240	75	520	46	315	35	240
Elongation in 2 in. or 50 mm (or 4 <i>D</i>), min, %:														
Basic minimum elongation for walls $\frac{5}{16}$ in. [8 mm] and over in thickness, strip tests, and for all small sizes tested in full section	35		30		30		30		22		28		18	[Note (1)]
When standard round 2 in. or 50 mm gage length or proportionally smaller size specimen with the gage length equal to 4 <i>D</i> (4 times the diameter) is used	28		22		22		22		16		...		...
For strip tests, a deduction for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness below $\frac{5}{16}$ in. [8 mm] from the basic minimum elongation of the following percentage points	1.75		1.50		1.50		1.50		1.25		1.50		...	
	[Note (2)]		[Note (2)]		[Note (2)]		[Note (2)]		[Note (2)]		[Note (2)]			

NOTES:

- (1) Elongation of Grade 11 is for all walls and for small sizes tested in full section.
- (2) The following table gives the calculated minimum values:

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

NOTE:

- (1) Calculated elongation requirements shall be rounded to the nearest whole number.

NOTE: The above table gives the computed minimum elongation values for each $\frac{1}{32}$ in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value is determined by the following equations.

Grade	Equation [Note (3)]
1	$E = 56t + 17.50$ [$E = 2.19t + 17.50$]
3	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
6	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
7	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
8	$E = 40t + 9.50$ [$E = 1.56t + 9.50$]
9	$E = 48t + 13.00$ [$E = 1.87t + 13.00$]

where:

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

TABLE 4
MAXIMUM HARDNESS NUMBER

Grade	Rockwell	Brinell
1	B 85	163
3	B 90	190
6	B 90	190
7	B 90	190
8	...	...
11	B 90	190

TABLE 5
IMPACT REQUIREMENTS FOR GRADES 1, 3, 6, 7, AND 9

Size of Specimen, mm	Minimum Average Notched Bar Impact Value of Each Set of Three Specimens [Note (1)]		Minimum Notched Bar Impact Value of One Specimen Only of a Set [Note (1)]	
	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

NOTE:

(1) Straight line interpolation for intermediate values is permitted.

TABLE 6
IMPACT TEMPERATURE

Grade	Impact Test Temperature	
	°F	°C
1	-50	-45
3	-150	-100
6	-50	-45
7	-100	-75
8	-320	-195
9	-100	-75

TABLE 7
IMPACT TEMPERATURE REDUCTION

Specimen Width Along Notch or Actual Material Thickness [Note (1)]		Temperature Reduction, Degrees Colder	
Inches	Millimeters	°F	°C
0.394	10 (standard size)	0	0
0.354	9	0	0
0.315	8	0	0
0.295	7.5 ($\frac{3}{4}$ standard size)	5	3
0.276	7	8	4
0.262	6.67 ($\frac{2}{3}$ standard size)	10	5
0.236	6	15	8
0.197	5 ($\frac{1}{2}$ standard size)	20	11
0.158	4	30	17
0.131	3.33 ($\frac{1}{3}$ standard size)	35	19
0.118	3	40	22
0.099	2.5 ($\frac{1}{4}$ standard size)	50	28

NOTE:

(1) Straight line interpolation for intermediate values is permitted.

SUPPLEMENTARY REQUIREMENTS

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

S1. Nonstandard Test Specimens

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

APPENDIX

(Nonmandatory Information)

X1. DETERMINATION OF TEMPERATURE REDUCTIONS

X1.1 Under the circumstances stated in 15.4, the impact test temperatures specified in Table 6 must be lowered. The following examples are offered to describe the application of the provisions of 15.4.

X1.1.1 When subsize specimens are used (see 14.1) 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 15.4 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 7 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 ($\frac{1}{3}$ 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).

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