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CERTIFICATE OF REGISTRATION

This is to certify that the
Quality Management System of

SKYLAND METAL & ALLOYS INC.

Address : Blackstone Bldg, 4th Floor, off. No 07, 185 , Dr. M.M Marg, (3rd Kumbharwada), Mumbai 400 004, Maharashtra, India

has been assessed and found in compliance
with requirements of

ISO 9001:2015
(Quality Management System)

Concerning the Following activities :

Manufacturers, Stockholding & Exporters of Stainless Steel, Carbon Steel, Alloys Steel, Monel, Inconel, Hastealloy Cupro Nickel, Copper, Brass in Pipes, Pipe Fittings, Flanges, Forge Fittings, Round Road, Plates, Sheets, Fasteners

Certificate No : QMS/SMA/616/3899

1st Surveillance Date Due on	20/06/2017	Date of initial registration	20/06/2016
2nd Surveillance Date Due on	20/06/2018	Date of certificate expiry	19/06/2019

Subject to the company maintaining its system to the required standard

Managing Director

PSA Quality Certification Limited

2nd Floor, Phool Singh Complex, Atta Sector- 27 Noida- 201301 (U.P.) India
Info@psacertification.com, www.psacertification.com
Accredited By American International Accreditation Organization
201 Los Gatos Saratoga Road, Suite 144, Los Gatos, CA 95030, USA

CERTIFICATE OF REGISTRATION

This is to certify that the
Environmental Management System of

SKYLAND METAL & ALLOYS INC.

Address : Blackstone Bldg, 4th Floor, off. No 07, 185 , Dr. M.M Marg, (3rd Kumbharwada), Mumbai 400 004, Maharashtra, India

has been assessed and found in compliance
with requirements of

ISO 14001:2015
(Environmental Management System)

Concerning the Following activities :

Manufacturers, Stockholding & Exporters of Stainless Steel, Carbon Steel, Alloys Steel, Monel, Inconel, Hastealloy Cupro Nickel, Copper, Brass in Pipes, Pipe Fittings, Flanges, Forge Fittings, Round Road, Plates, Sheets, Fasteners

Certificate No : EMS/SMA/616/3900

1st Surveillance Date Due on	20/06/2017	Date of initial registration	20/06/2016
2nd Surveillance Date Due on	20/06/2018	Date of certificate expiry	19/06/2019

Subject to the company maintaining its system to the required standard

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Managing Director

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CERTIFICATE OF REGISTRATION

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has been assessed and found in compliance
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(Occupational Health and Safety Management)

Concerning the Following activities :

Manufacturers, Stockholding & Exporters of Stainless Steel, Carbon Steel, Alloys Steel, Monel, Inconel, Hastealloy Cupro Nickel, Copper, Brass in Pipes, Pipe Fittings, Flanges, Forge Fittings, Round Road, Plates, Sheets, Fasteners

Certificate No : OHS/SMA/616/3902

1st Surveillance Date Due on	20/06/2017	Date of initial registration	20/06/2016
2nd Surveillance Date Due on	20/06/2018	Date of certificate expiry	19/06/2019

Subject to the company maintaining its system to the required standard

PSA CERT

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Designation: A 1053/A 1053M – 06

Standard Specification for Welded Ferritic-Martensitic Stainless Steel Pipe[1]

This standard is issued under the fixed designation A 1053/A 1053M; 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 covers seam welded ferritic-martensitic (dual phase) stainless steel pipe intended for abrasive and general corrosion service. Nominal sizes are NPS 2 to NPS 36 inclusive, with nominal (average) wall thickness up to 0.75-in. (19 mm).

1.2 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 is specified in the order.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

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

A 1010/A 1010M Specification for Higher-Strength Martensitic Stainless Steel Plate, Sheet, and Strip

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *ANSI/ASME Standards:*[3]

B1.20.1 Pipe Threads, General Purpose

B36.10 Welded and Seamless Wrought Steel Pipe

B36.19 Stainless Steel Pipe

2.3 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[4]

3. Terminology

3.1 *Definitions*:

3.1.1 The definitions in Specification A 999/A 999M and Terminology A 941 are applicable to this specification.

4. Ordering Information

4.1 Orders for material to this specification shall conform to the requirements of the current edition of Specification A 999/A 999M.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

6. Materials and Manufacture

6.1 *Material*:

6.1.1 The material for this pipe shall conform to Specification A 1010/A 1010M Grade 50 dual phase stainless steel.

6.2 *Manufacture*:

6.2.1 The pipe shall be made using Electric Resistance Welding (ERW) or an automatic fusion welding process with no addition of filler metal during the welding process.

6.2.2 Welded pipe of NPS 14 and smaller shall have a single longitudinal weld. Welded pipe of a size larger than NPS 14 shall have a single longitudinal weld or shall be produced by forming and welding two longitudinal sections of flat stock when approved by the purchaser. All weld tests, examinations, inspections or treatments shall be performed on each weld seam.

6.2.3 The pipe shall be free of scale and contaminating surface iron particles. Pickling, blasting or surface finishing is

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[1] This test method 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.

Current edition approved Oct. 1, 2006. Published November 2006.

[2] 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.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

not mandatory. The purchaser is permitted to require that a passivating treatment be applied to the finished pipe.

6.3 *Heat Treatment*—All pipe shall be made from heat-treated strip or plate, cold formed and welded. The weld may be induction strip tempered, at the discretion of the buyer, at a minimum temperature of 1300 °F [700 °C], but not exceeding 1400 °F [760 °C].

7. Chemical Composition

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

8. Product Analysis

8.1 At the request of the purchaser, an analysis of one length of flat rolled stock from each heat, or two pipes from each *lot*, shall be made by the manufacturer. A *lot* of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel:

NPS Designator	Lengths of Pipe in *Lot*
Under 2	400 or fraction thereof
2 to 5	200 or fraction thereof
6 and over	100 or fraction thereof

8.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements of Section 7.

8.3 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in Section 7, an analysis of each pipe from the same heat or *lot* may be made, and all pipes conforming to the requirements shall be accepted.

9. 9. Permitted Variations in Wall Thickness and Diameter

9.1 The wall thickness of the pipe shall be within the tolerances specified in Table 2, except that the weld area shall not be limited by the "Over" tolerance.

9.2 The outside diameter to be used for inspection for compliance with this requirement when ordered by NPS and schedule number is shown in Table 3. Other diameters and wall thicknesses may be used when specified in the purchase order. Standard sizes of NPS pipe are listed in Table 4.

10. Tensile Requirements

10.1 The tensile properties of the pipe shall conform to the requirements prescribed in Table 5.

11. Mechanical Tests Required

11.1 *Mechanical Testing Lot Definition*—The term *lot* for mechanical tests shall be as follows:

11.1.1 The *lot* size shall be that defined in 8.1.

11.1.2 The minimum number of tests shall be one (1) test per *lot*.

11.2 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for *lots* of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for *lots* of more than 100 pipes.

11.3 *Flattening Test*—Flattening tests shall be made on a sufficient number of pipes to constitute 1 % of the *lot*, but at least one length of pipe. Flattening tests shall be made on specimens from two tubes for *lots* of more than 100 pipes.

11.4 A transverse guided face bend test may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A 370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 1 % of the *lot* shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

12. Hydrostatic or Nondestructive Electric Test

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

12.2 The hydrostatic test shall be in accordance with Specification A 999/A 999M, unless specifically exempted under the provisions of 12.3.

12.3 For pipe whose dimensions equal or exceed NPS 10, the purchaser, with the agreement of the manufacturer, is permitted to waive the hydrostatic test requirement when in lieu of such test the purchaser performs a system test. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory marking the letters "NH."

12.4 The nondestructive electric test shall be in accordance with Specification A 999/A 999M.

13. Lengths

13.1 Pipe lengths shall be in accordance with the following practice:

13.1.1 The standard length, unless otherwise agreed upon, shall be 20 ft [6 m] with the permitted range of 17 to 24 ft [5.2 to 7.3 m]. Shorter lengths are acceptable, but the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

13.1.2 For slurry applications, to minimize turbulence at the jointers, the continuous length is 50 ft [15.2 m] with a permitted range of 48 to 54 ft [14.6 to 16.5 m].

13.1.3 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and no pipe shall be more than ¼ in. [6 mm] over the specified length.

13.1.4 No jointers are permitted unless otherwise specified and agreed upon between the purchaser and manufacturer.

14. Workmanship, Finish, and Appearance

14.1 The finished pipes shall be straight within ≤ 0.2 % of length of pipe using a taught wire the length of the pipe.

14.2 The finished pipes shall have a workmanlike finish. Removal of imperfections by grinding is permitted, providing the wall thickness is not decreased to less than that permitted in Section 9 of Specification A 999/A 999M.

15. Repair by Welding

15.1 For welded pipe whose diameter ≥ NPS 4, and whose nominal wall thickness ≥ 0.188 in. [4.77 mm], it is permitted to make weld repairs with the addition of compatible filler

TABLE 1 Chemical Composition Requirements, %[A]

UNS Designation[B]	Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Nitrogen	Other Elements
S41003	0.030	1.50	0.040	0.030	1.00	10.5–12.5	1.50	0.030	...

[A]Maximum, unless range or minimum is indicated.
[B]Designation established in accordance with Practice E 527 and SAE J 1086.

TABLE 2 Permitted Variations in Wall Thickness

NPS Designator (All t/D ratios)	Tolerance, % from Nominal	
	Over	Under
Up to 2 ½ incl.	20	12.5
3 to 18 incl.	22.5	12.5
20 and larger	15.0	12.5

TABLE 3 Permitted Variations in Outside Diameter

NPS Designator	Over	Under
2 through 18	1 %	1 %
20 and over	0.75 %	0.75 %

metal to the weld seam or parent metal when approved by the purchaser. Repair welding shall meet the requirements of Specification A 999/A 999M.

15.2 The composition of the deposited filler metal shall be suitable for the Specification A 1010/A 1010M ferritic-martensitic plate.

15.3 Pipes that have had weld seam repairs with filler metal shall be identified in the stencil with "WR" and shall be so identified on the certificate of tests.

16. Certification

16.1 In addition to the information required by Specification A 999/A 999M, the certified mill test report (CMTR) shall state whether or not the material was hydrostatically tested. If the material was nondestructively tested, the certification shall so state and shall state which practice was followed and what reference discontinuities were used.

17. Marking

17.1 In addition to the marking specified in Specification A 999/A 999M, the marking shall include the NPS (nominal pipe size) or outside diameter, the schedule number or average or minimum wall thickness, specification number, alloy grade, heat number, NH when hydrostatic testing is not performed and ET or UT when eddy current or ultrasonic testing is performed. If the seam weld is x-rayed, the line marking shall so state. The markings also shall include the manufacturer's private identifying mark, and the marking required by 15.3, if applicable. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight per foot [weight per metre].

18. Government Procurement

18.1 Scale Free for Government Procurement:

18.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry, contract or order, for agencies of the U.S. Government where scale free pipe or tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specifications.

18.1.2 The requirements of Specification A 999/A 999M for pipe and Specification A 1016/A 1016M for tubes shall be applicable when pipe or tube is ordered to this specification.

18.1.3 *Ordering Information*—Orders for material under this specification shall include the following in addition to the requirements of Section 4:

18.1.3.1 Pipe or tube,

18.1.3.2 Part Number,

18.1.3.3 Ultrasonic inspection if required,

18.1.3.4 If shear wave is to be conducted in two opposite circumferential directions, and

18.1.3.5 Level of preservation and packing required.

19. Keywords

19.1 dual phase; ferritic-martensitic stainless steel; stainless steel pipe; steel pipe; welded steel pipe

TABLE 4 Dimensions of Welded Pipe

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[A]		Schedule 10S[A]		Schedule 40S and Standard		Schedule 80S and Extra Heavy	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
2	2.375	60.33	0.065	1.65	0.109	2.77	0.154	3.91	0.218	5.54
2 ½	2.875	73.03	0.083	2.11	0.120	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120	3.05	0.216	5.49	0.300	7.62
3 ½	4.000	101.60	0.083	2.11	0.120	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109	2.77	0.134	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109	2.77	0.148	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134	3.40	0.165	4.19	0.365	9.27	0.500[B]	12.70[B]
12	12.750	323.85	0.156	3.96	0.180	4.57	0.375[B]	9.52[B]	0.500[B]	12.75[B]
14	14.000	355.60	0.156	3.96	0.188[B]	4.78[B]	...	...	...	...
16	16.000	406.40	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
18	18.000	457.20	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
20	20.000	508.00	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
22	22.000	558.80	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
24	24.000	609.60	0.218	5.54	0.250	6.35	...	...	...	...
30	30.000	762.000	0.250	6.35	0.312	7.92	...	...	...	...
32	32.000	812.80	...	...	0.312[C]	7.92[C]	...	...	...	...
34	34.000	863.60	...	...	0.312[C]	7.92[C]	...	...	...	...
36	36.000	914.40	...	...	0.312[C]	7.92[C]	...	...	...	...

[A]Schedules 5S and 10S wall thicknesses do not permit threading in accordance with ANSI B1.20.1.
[B]These do not conform to ANSI/ASME B36.10.
[C]These sizes are not included in ANSI/ASME B36.19.

TABLE 5 Mechanical Test Requirements

Grade	Yield Strength, min, ksi [MPa]	Tensile Strength, min, ksi [MPa]	Elongation in 2 in. [50 mm], min, %	Brinell Hardness, max
50	50 [350]	70 [485]	18	360

Designation: A 1047/A 1047M – 05

Standard Test Method for Pneumatic Leak Testing of Tubing[1]

This standard is issued under the fixed designation A 1047/A 1047M; 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 test method provides procedures for the leak testing of tubing using pneumatic pressure. This test method involves measuring the change in pressure inside the tubing over time. There are three procedures that may be used, all of which are intended to be equivalent. It is a qualitative not a quantitative test method. Any of the three procedures are intended to be capable of leak detection and, as such, are intended to be equivalent for that purpose.

1.2 The procedures will produce consistent results upon which acceptance standards can be based. This test may be performed in accordance with the Pressure Differential (Procedure A), the Pressure Decay (Procedure B), or the Vacuum Decay (Procedure C) method.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The values stated in either inch-pound 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 shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 1016 Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

3. Terminology

3.1 *Definitions*—The definitions in Specification A 1016 are applicable to this test method.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *actual starting pressure (P_0 actual)*—the actual starting pressure at time zero on each test cycle.

3.2.2 *calibration hole*—a device (such as a crimped capillary, or a tube containing a hole produced by laser drilling) certified to be of the specified diameter.

3.2.3 *control volume*—fixed volume that is pressurized to compare against an identical pressure contained in one tube under test.

3.2.4 *electronic control device (ECD)*—an electronic system to accumulate input from limit switches and transmitters providing corresponding outputs to solenoid valves, acoustic alarm devices, and visual displays

3.2.5 *pressure change* (ΔP)—the smallest pressure change in a tube, reliably detected by a pressure sensitive transmitter.

3.2.6 *pressure sensitive transmitters*—pressure measuring and signaling devices that detect extremely small changes in pressure, either between two tubes, a tube and a control volume, or a tube and the ambient atmosphere.

3.2.7 *reference standard*—a tube or container containing a calibration hole. The calibration hole may either be in a full length tube, or in a short device attached to the tube or container.

3.2.8 *starting pressure* (P_0)—the test starting pressure set in the test apparatus ECD.

3.2.9 *theoretical hole*—a hole that will pass air at a theoretical rate as defined by the equations given in Appendix X1.2.

3.2.10 *threshold pressure* (P_T)—test ending pressure limit after the allowed test time; the pressure value that must be crossed to determine reject status. $P_T = P_0\ actual - \Delta P$ for pressure decay, and $P_T = P_0\ actual + \Delta P$ for vacuum decay.

4. Summary of Test Method

4.1 *Procedure A, Pressure Differential*, measures the drop in pressure over time as a result of air escaping from inside one tube when compared to another tube at an identical pressure, or one tube against a control volume at identical pressure. (See Refs **(1)** and **(2)**)

4.2 *Procedure B, Pressure Decay*, measures the drop in pressure over time as a result of air escaping from the tube.

4.3 *Procedure C, Vacuum Decay*, involves evacuating the tubing to suitably low pressure and measuring the increase in pressure caused by gas entering the tubing.

[1] This test method 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.

Current edition approved Dec. 1, 2005. Published December 2005.

[2] 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.

5. Significance and Use

5.1 When permitted by a specification or the order, this test method may be used for detecting leaks in tubing in lieu of the air underwater pressure test.

6. Apparatus

6.1 An electronic control device (ECD) controls all operations of the test method by accepting inputs from limit switches and transmitters, and by providing corresponding pass/fail outputs to solenoid valves, acoustic alarm devices, and visual displays. The pass/fail determination is achieved by a comparison of the data input from pressure transducers with a standard accept/reject criterion measured over the set test time.

6.2 The test apparatus may have the capability for single- or multi-tube testing. It shall be designed to detect a small predetermined pressure change during the testing cycle. It is intended that the apparatus be fully automated and equipped with suitable instrumentation for the purpose of the test. This instrumentation may include, but is not limited to the following:

6.2.1 Internal transducers for calibration tests,

6.2.2 Differential pressure and leak rate diagnosis,

6.2.3 Control panel display for reporting digital or analog outputs,

6.2.4 Absolute or differential pressure transducers, or both,

6.2.5 Internal timing device,

6.2.6 Failure lamps, and

6.2.7 Automatic shutdown capability.

7. Hazards

7.1 **Warning—**In addition to other precautions, high pressure air is employed during the testing process.

8. Calibration

8.1 Apparatus calibration shall be performed using a reference standard, with adjustments of Starting Pressure (P_0), Pressure Change (ΔP), and test time. Test time is dependent upon starting pressure, allowed pressure change, tube internal volume, hole diameter, and is calculated using the equation in Appendix X1. Actual test time may be longer than the calculated value and shall be adjusted as necessary for the apparatus to cross the threshold pressure and cause the system to automatically shut down.

8.2 Verify that all failure lights are illuminated during the calibration.

8.3 Unless otherwise specified, apparatus calibration shall be made at twelve month intervals maximum.

8.4 Recalibrate the test apparatus prior to use whenever any pressure sensing component is replaced or modified.

8.5 Calibrate the calibration hole at twelve month intervals maximum. It is recommended that the device containing the calibration hole be stored in an inert atmosphere and cleaned with high pressure nitrogen.

8.6 Calibrate all pressure gauges and pressure transducers at twelve month intervals maximum.

8.7 Unless otherwise agreed to by producer and purchaser, the minimum calibration hole size in the reference standard shall be 0.003-in. diameter. Calibration with smaller holes may not be repeatable due to fouling and plugging. (See Ref **(5)**)

9. Procedure

9.1 Perform pneumatic leak testing after all process operations, including cold work, heat treatment, and straightening.

9.2 Clean and dry the tubes before testing. Remove loose scale from the inside and outside surfaces of the tubes.

9.3 Actual test time is calculated in accordance with the parameters of the test using the appropriate equation in X1.2.

9.4 *Test Cycle for Procedure A, Pressure Differential*:

9.4.1 Pressurize the tubes in pairs, or a single tube and a known control volume, to a pressure greater than 33 psia with clean and dry compressed air.

9.4.2 Allow the system to stabilize and measure the actual Starting Pressure (P_0 *actual*). P_0 *actual* must be within 10 % of P_0 for a valid test.

9.4.3 The apparatus is to calculate and set the Threshold Pressure where $P_T = P_0\ actual - \Delta P$.

9.4.4 Isolate the tubes in pairs or a single tube and a known control volume.

9.4.5 Measure the pressure at the end of the test period. The tubes or tube have/has passed the test if the pressure has not crossed the threshold pressure P_T. If the threshold pressure has been crossed, then the tubes or tube have failed. When a failure occurs while testing tubes in pairs, the individual tubes may be tested with other tubes to determine which tube failed.

9.5 *Test Cycle for Procedure B, Pressure Decay*:

9.5.1 Pressurize the tube to a pressure greater than 33 psia with clean and dry compressed air.

9.5.2 Allow the system to stabilize and measure the actual Starting Pressure (P_0 *actual*). P_0 *actual* must be within 10 % of P_0 for a valid test.

9.5.3 The apparatus is to calculate and set the Threshold Pressure where $P_T = P_0\ actual - \Delta P$.

9.5.4 Measure the pressure at the end of the test cycle. The tube has passed the test if the pressure has not crossed the threshold pressure P_T.

9.6 *Test Cycle for Procedure C, Vacuum Decay*:

(See Refs **(3)** and **(4)**)

9.6.1 Draw a vacuum on the tube to a pressure below 6 psia.

9.6.2 Allow the system to stabilize and measure the actual Starting Pressure (P_0 *actual*). P_0 *actual* must be within 10 % of P_0 for a valid test.

9.6.3 The apparatus is to calculate and set the Threshold Pressure where $P_T = P_0\ actual + \Delta P$.

9.6.4 Measure the pressure at the end of the test cycle. The tube has passed the test if the pressure has not crossed the threshold pressure P_T.

10. Report

10.1 Report the following information:

10.1.1 Tubing identification, and

10.1.2 Procedure used for the satisfactory results of the test.

10.2 Maintain records of the test parameters and results.

11. Precision and Bias

11.1 No information is presented about either the precision or bias of this test method for measuring the leak capability since the test is non-quantative.

12. Keywords

12.1 leak testing; pneumatic testing

APPENDIX

(Nonmandatory Information)

X1. EXAMPLE CALCULATIONS AND APPLICATIONS

X1.1 Nomenclature

P_a = absolute atmospheric pressure, in psia = 14.69 psia
P_0 = initial absolute pressure inside the tube, in psia
P_f = final absolute pressure inside the tube, in psia
ΔP = absolute pressure change inside the tube during the test period, in psia
V = tube internal volume, in ft^3 or in.^{3} as noted
A = through wall hole cross section area, in ft^2 or in.^{2} as noted
d = through wall hole diameter, in inches
t = test or decay time, in seconds
T = absolute air temperature inside the tube, in °R = °F + 460; T may be assumed to be 70 °F = 530 °R
M = mass of air contained in a tube, in lbm
ΔM = mass change inside the tube during the test period, in lbm
$\dot{m}$ = mass flow rate of air leaking through a hole, in lbm/sec
ρ_a = density of air at standard conditions = 0.0765 lbm/ft^3
R = gas constant for air = 53.3 ft·lbf/lbm·°R

X1.2 Theoretical Time Equations

X1.2.1 *Pressure Differential and Pressure Decay Time*:

$$t = 1.65 \times 10^{-4} \frac{V}{d^2} \left| \ln \frac{P_0 - \Delta P}{P_0} \right| \quad \text{(X1.1)}$$

with units V = in.^{3}, d = in.,
and assuming T = 530 °R

X1.2.2 *Vacuum Decay Time*:

$$t = 1.65 \times 10^{-4} \frac{V}{d^2} \frac{\Delta P}{P_a} \quad \text{(X1.2)}$$

with units V = in.^{3}, d = in.,
and assuming T = 530 °R

NOTE X1.1—The vacuum equations can be used for the pressure equations by substituting P_0 for P_a with the provision that ΔP is less than 1 psi.

X1.3 Derivation

X1.3.1 *From Fliegner's Formula* (see Ref **(6)**, page 85):

$$\frac{\dot{m}\sqrt{T}}{AP} = 0.532 \text{ or } \dot{m} = \frac{0.532AP}{\sqrt{T}} \text{ with units } A = \text{ft}^2, P = \frac{\text{lbf}}{\text{ft}^2} \quad \text{(X1.3)}$$

X1.3.1.1 Boundary condition for choked flow (see Ref **(6)**, page 84):

$$\frac{P_a}{P_f} < 0.528 \text{ for pressure decay, } \frac{P_f}{P_a} < 0.528 \text{ for vacuum decay} \quad \text{(X1.4)}$$

X1.3.2 *Ideal Gas Law*:

$$PV = MRT \text{ or } P = \frac{MRT}{V} \quad \text{(X1.5)}$$

X1.3.3 *Pressure Decaying from a Control Volume*:

$$\frac{dP}{dt} = \frac{RT}{V}\frac{dM}{dt} = \frac{RT}{V}\dot{m} \quad \text{(X1.6)}$$

X1.3.3.1 Substituting Fliegner's formula:

$$\frac{dP}{dt} = \frac{RT}{V}\frac{0.532AP}{\sqrt{T}} = \frac{28.36AP\sqrt{T}}{V} \quad \text{(X1.7)}$$

$$\frac{dP}{P} = \frac{28.36A\sqrt{T}}{V} dt = \tau \cdot dt$$

$$\int \frac{1}{P} dP = \int \tau \cdot dt$$

$$t = \frac{V}{28.36A\sqrt{T}} \left| \ln \frac{P_0 - \Delta P}{P_0} \right|$$

with V in ft^3, A in ft^2, P can be any unit

$$t = 1.65 \times 10^{-4} \frac{V}{d^2} \left| \ln \frac{P_0 - \Delta P}{P_0} \right|$$

with units V = in.^{3}, d = in.,
and assuming T = 530 °R

X1.3.4 *Vacuum Decay into a Control Volume*:

X1.3.4.1 Because the high pressure source is the atmosphere and is of infinite quantity, pressure in a control volume increases at a linear rate.

$$t = \frac{\Delta M}{\dot{m}} \quad \text{(X1.8)}$$

$$\Delta M = V\Delta\rho$$

$$\rho_0 = \frac{P_0}{P_a}\rho_a, \rho_f = \frac{P_f}{P_a}\rho_a, \Delta\rho = \frac{\Delta P}{P_a}\rho_a = 0.0765\frac{\Delta P}{P_a}$$

X1.3.4.2 Again using Fliegner's formula:

$$\dot{m} = \frac{0.532AP_a}{\sqrt{T}} \text{ with units } A = \text{ft}^2, P_a = \frac{\text{lbf}}{\text{ft}^2} \quad \text{(X1.9)}$$

$$t = \frac{\Delta M}{\dot{m}} = \frac{0.0765V\frac{\Delta P}{P_a}}{\frac{0.532AP_a}{\sqrt{T}}} = 0.1438\frac{V\sqrt{T}}{AP_a}\frac{\Delta P}{P_a}$$

Using $P_a = 2115$ psfa (14.69 psia)

$$t = 6.8 \times 10^{-5}\frac{V\sqrt{T}}{A}\frac{\Delta P}{P_a}$$

with units $V = \text{ft}^3$, $A = \text{ft}^2$, $T = °R$,

and P can be any unit

$$t = 1.65 \times 10^{-4}\frac{V}{d^2}\frac{\Delta P}{P_a}$$

with units $V = \text{in.}^3$, $d = \text{in.}$,

and assuming $T = 530\ °R$

X1.4 Application Example

X1.4.1 For *Procedure A, Pressure Differential*, determine the pressure decay time of a 1 in. OD by 0.050 in. wall by 60 ft long tube with a 0.003 in. diameter hole; the test apparatus initial pressure is 110 psig with 0.031 psig allowed pressure drop.

X1.4.1.1 Using the equation given in X1.2.1:

$$t = 1.65 \times 10^{-4}\frac{V}{d^2}\left|\ln\frac{P_0 - \Delta P}{P_0}\right| \quad \text{(X1.10)}$$

$V = 458\ \text{in.}^3$

$d = 0.003$ in.

$P_0 = 110 + 14.69 = 124.69$ psia

$\Delta P = 0.031$ psia

$$t = 1.65 \times 10^{-4}\frac{458}{0.003^2}\left|\ln\frac{124.69 - 0.031}{124.69}\right|$$

$$= \frac{1.65 \times 10^{-4} \times 458 \times 2 \times 10^{-4}}{9 \times 10^{-6}}$$

$= 1.7$ sec

X1.5 Graph

X1.5.1 The graph in Fig. X1.1 displays decay time as a function of tube internal volume assuming a 0.003 in. hole diameter, 110 psig initial pressure, and 0.031 psig allowed pressure drop.

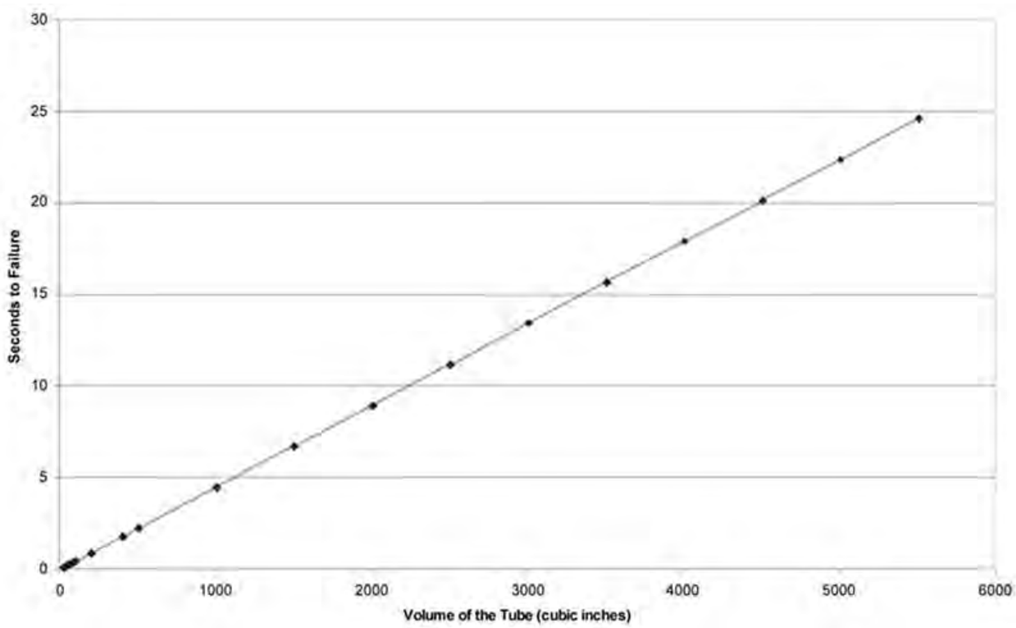

FIG. X1.1 Pressure Differential Standardization 110 psig @ 0.031 Threshold 0.003 in. Leak Diameter

REFERENCES

(1) An Improved Method for Testing Stainless and Titanium Tubing – PWR- Vol. 34, 1999 Joint Power Generation Conference Volume 2 ASME 1999. Dennis J. Schumerth & Scott Johnson, Valtimet, Inc.
(2) Pressure Differential Testing of Tubing, ASTM Material Research Standards, ASTM Vol. 1, No. 7, July 1961.
(3) A Users Guide to Vacuum Technology, John O'Hanlon, Wiley Interscience.
(4) Foundations of Vacuum Science and Technology, J. M. Lafferty, Wiley Inerscience.
(5) ASTM A01.10 Task Group 961T-6 Reports:
Nov. 2000, Valtimet Report AUW vs., P-D
May, 2001, Rath Manufacturing Co. Report on Leak Testing
(6) The Dynamics and Thermodynamics of Compressible Fluid Flow, Volume I, Ascher H. Shapiro, The Roland Press Company, 1953.

Designation: A 1037/A 1037M – 05

Standard Specification for Steel Line Pipe, Black, Furnace-Butt-Welded[1]

This standard is issued under the fixed designation A 1037/A 1037M; 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 covers furnace-butt-welded, black, plain-end or threaded-end, steel pipe for use in the conveyance of fluids under pressure. Pipe in sizes NPS ½ to 4, inclusive, with nominal wall thickness 0.350 in. [8.9 mm] or less, as given in ASME B36.10M is included. Pipe having other dimensions, in this size range, may be furnished provided such pipe complies with all other requirements of this specification.

1.2 For plain-end pipe, it is intended that the pipe be capable of being circumferentially welded in the field when welding procedures in accordance with the requirements of the applicable pipeline construction code are used.

1.3 The values stated in either inch-pound units or in SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values in each system are not exact equivalents; therefore, each system is to be used independently of the other.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy and Austenitic Alloy Steel Tubes

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 751 Test Methods, Practices and Terminology for Chemical Analysis of Steel Products

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

2.2 *ASME Standard:*

ASME B36.10M Welded and Seamless Wrought Steel Pipe[3]

2.3 *API Standards:*

5L Specification for Line Pipe[4]

5B Specification for Threading, Gauging, and Thread Inspection of Casing, Tubing, and Line Pipe Threads[4]

3. Terminology

3.1 *Definitions*—For terminology used in this specification, refer to Terminology A 941.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *furnace-butt-welded pipe, n*—pipe produced in multiple lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt joint forge welded by the mechanical pressure developed in rolling the hot-formed skelp through a set of round pass welding rolls.

3.2.2 *lot, n*—a quantity of pipe of the same ordered diameter, heat, wall thickness, and grade as given in Table 1.

3.2.3 *specified outside diameter (OD), n*—the outside diameter specified in the purchase order or the outside diameter listed in ASME B36.10M for the nominal pipe size specified in the purchase order.

4. General Requirements

4.1 Pipe furnished under this specification shall conform to the applicable requirements of Specification A 530/A 530M unless otherwise provided herein.

5. Ordering Information

5.1 It is the purchaser's responsibility to specify in the purchase order all information necessary to purchase the needed material. Examples of such information include, but are not limited to, the following:

5.1.1 Specification designation and year-date,

5.1.2 Quantity (feet or metres),

5.1.3 Grade (A or B),

5.1.4 Size (either nominal (NPS) or outside diameter, and wall thickness),

5.1.5 Length,

5.1.6 End finish (plain-end, special plain-end, or threaded-end, see 15.1),

5.1.7 End use of the pipe,

5.1.8 Special requirements, and

5.1.9 Bar coding (see 18.3).

6. Materials and Manufacture

6.1 The steel shall be made by one or more of the following processes: basic-oxygen, electric-furnace, or open-hearth.

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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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Jan. 1, 2005. Published January 2005.

[2] 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.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

[4] Available from The American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005.

TABLE 1 Lot Size and Sample Size for Mechanical Testing

Size Designation	Lot Size	Sample Size
<NPS 2	25 tons [23 Mg] or fraction thereof	1
NPS 2 through NPS 4	50 tons [45 Mg] or 500 lengths, or fraction thereof	1

6.2 The pipe shall be made by the furnace-butt-welding process.

7. Chemical Composition

7.1 The steel shall contain, by heat and product analyses, no more than 0.25 % carbon, 1.20 % manganese, 0.045 % sulfur, and 0.045 % phosphorus.

7.2 As a minimum, the required analysis shall contain the following elements: carbon, manganese, phosphorus, sulfur, chromium, columbium, copper, molybdenum, nickel, silicon, and vanadium.

7.3 Product analyses shall be made on at least two samples from each heat of steel.

7.4 All analyses shall be in accordance with Test Methods, Practices, and Terminology A 751.

7.5 If one or both of the product analyses representing a heat fails to conform to the specified requirements, the heat shall be rejected, or analyses shall be made on double the original number of test samples that failed, each of which shall conform to the specified requirements.

8. Tensile Requirements

8.1 The material shall conform to the requirements for tensile properties given in Table 2 and in 8.4.

8.2 The yield strength corresponding to a total extension under load of 0.5 % of the gage length shall be determined.

8.3 Longitudinal tests shall be performed for all pipe. Such tests shall be either strip specimens taken 90° from the weld or full section specimens, at the option of the manufacturer.

8.4 The minimum elongation in 2 in. [50 mm] for each grade shall be that determined by the following equation:

$$e = CA^{0.2}/U^{0.9} \tag{1}$$

TABLE 2 Tensile Requirements

Grade	Yield Strength, min		Tensile Strength, min	
	psi	MPa	psi	MPa
A	30 000	205	48 000	330
B	35 000	240	60 000	415

where:

e = minimum elongation in percent, rounded to the nearest percent,
C = constant = 625 000 [1940],
A = cross-sectional area of the tensile test specimen in in.^{2} [mm^2], based upon the specified outside diameter or the nominal specimen width and the specified wall thickness, rounded to the nearest 0.01 in.^{2} [1 mm^2]. If the area thus calculated is greater than 0.75 in.^{2} [485 mm^2], the value of 0.75 in.^{2} [485 mm^2] shall be used, and
U = specified minimum tensile strength, psi [MPa].

9. Flattening Test

9.1 A test specimen at least 4 in. [100 mm] in length shall be flattened cold between parallel plates in three steps, with the weld located either 0° or 90° from the line of direction of force, as required in 9.2.1. Except as allowed by 9.3, during the first step, which is a test for ductility of the weld, no cracks or breaks on the inside, outside, or end surfaces at the weld shall be present before the distance between the plates is less than two thirds of the specified diameter of the pipe. As a second step, the flattening shall be continued as a test for ductility away from the weld. During the second step, no cracks or breaks on the inside, outside, or end surfaces away from the weld, shall be present before the distance between the plates is less than one third of the specified outside diameter of the pipe but is not less than five times the wall thickness of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the test specimen breaks or the opposite walls of the test specimen meet. Evidence of laminated or unsound material or of incomplete weld that is revealed by the flattening test shall be cause for rejection.

9.2 The flattening test specified in 9.1 shall be made as follows:

9.2.1 Test specimens taken from the front end of the first pipe intended to be supplied from each coil and the back end of the last pipe intended to be supplied from each coil shall be flattened with the weld located at 90° from the line of direction of force.

9.2.2 Test specimens taken from pipe at any two locations intermediate to the front end of the first pipe and the back end of the last pipe intended to be supplied from each coil shall be flattened with the weld located at 0° from the line of direction of force.

9.3 When low *D*-to-*t* ratio pipe is tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the *D*-to-*t* ratio is less than 10.

10. Hydrostatic Test

10.1 Each length of pipe shall be subjected to the hydrostatic test without leakage through the weld seam or the pipe body.

10.2 Each length of pipe NPS 2 or larger shall be tested, by the manufacturer, to a minimum hydrostatic pressure calculated from the following relationship:

Inch-Pound Units:

$$P = 2\,St/D \times C \tag{2}$$

SI Units:

$$P = 2000\,St/D \times C \tag{3}$$

where:
P = minimum hydrostatic test pressure, psi [kPa],
S = specified minimum yield strength, psi [MPa],
t = specified wall thickness, in. [mm],
D = specified outside diameter, in. [mm], and
C = 0.60.

10.3 For pipe sizes smaller than NPS 2, the test pressures shall be as given in Table 3. For pipe in sizes smaller than NPS 2 with wall thicknesses lighter than those listed, the test pressure for the next heavier listed specified wall thickness shall be used. For intermediate specified outside diameters smaller than NPS 2, the test pressures given for the next smaller specified outside diameter shall be used.

10.4 When computed test pressures are not an exact multiple of 10 psi [100 kPa], they shall be rounded to the nearest 10 psi [100 kPa].

10.5 The minimum hydrostatic test pressure required to satisfy these requirements need not exceed 3000 psi [20 700 kPa]. This does not prohibit testing at a higher pressure at the manufacturer's option. The hydrostatic test pressure shall be maintained for not less than 5 s for all pipe sizes.

11. Nondestructive Testing

11.1 The weld seam of each length of pipe NPS 2 [DN 50] or larger shall be tested with a nondestructive electric test as follows:

11.1.1 *Ultrasonic or Electromagnetic Inspection*—Any equipment utilizing the ultrasonic or electromagnetic principles and capable of continuous and uninterrupted inspection of the weld seam shall be used. The equipment shall be checked with an applicable reference standard as described in 11.2 at least once every 8 h of inspection to demonstrate the effectiveness of the inspection procedures. The equipment shall be adjusted to produce well-defined indications when the reference standard is scanned by the inspection unit in a manner simulating the inspection of the product. The location of the equipment shall be at the manufacturer's option.

11.2 *Reference Standards*—Reference standards shall have both the outside diameter and wall thickness within the tolerances specified for the production pipe to be inspected and may be of any convenient length as determined by the pipe manufacturer. Reference standards shall be either full sections or coupons taken from the pipe. Reference standards shall contain machined notches as shown in Fig. 1, one on the inside surface and one on the outside surface, or a drilled hole as shown in Fig. 1, at the option of the pipe manufacturer. The notches shall be parallel to the weld seam, and shall be separated by a distance sufficient to produce two separate and distinguishable signals. The ⅛-in. [3-mm] drilled hole shall be drilled through the wall and perpendicular to the surface of the reference standard as shown in Fig. 1. Care should be taken in the preparation of the standard to ensure freedom from fins, other edge roughness, and distortion of the pipe.

NOTE 1—The calibration standards shown in Fig. 1 are convenient standards for calibration of nondestructive testing equipment. The dimensions of such standards should not be construed as the minimum size imperfection detectable by such equipment.

11.3 *Acceptance Limits*—Table 4 gives the height of acceptance limit signals in percent of the height of signals produced by the calibration standards. Imperfections in the weld seam that produce a signal greater than the acceptance limit given in Table 4 shall be considered defects unless the pipe manufacturer can demonstrate that the imperfection does not reduce the effective wall thickness to below 87.5 % of the specified wall thickness.

11.4 Surface condition, operator qualification, extent of examination, and standardization procedure shall be in accordance with the provisions of Specification A 450/A 450M.

12. Number of Tests

12.1 Tension testing shall be performed on a lot basis, with the lot size and sample sizes as given in Table 1.

13. Retests

13.1 If the results of the tension test for any lot fails to conform to the applicable requirements given in Table 2, retests are permitted to be made on additional pipe of double the original number from the same lot, each of which shall conform to the specified requirements.

13.2 If any flattening test fails to conform to the requirements specified in 9.1, each length in the failed multiple shall be rejected or flattening tests shall be made using test specimens taken from each end of each individual length in the failed multiple. Such tests shall be made with the weld alternately at 0° and 90° from the line of direction of force.

14. Dimensions, Mass, and Permissible Variations

14.1 The dimensions and masses per unit length of some of the pipe sizes included in this specification are given in ASME

TABLE 3 Hydrostatic Test Pressure

NPS Designator	Outside Diameter		Wall Thickness		Test Pressure, min	
	in.	mm	in.	mm	psi	kPa
½	0.840	21.3	0.109	2.8	700	4800
			0.147	3.7	850	5900
¾	1.050	26.7	0.113	2.9	700	4800
			0.154	3.9	850	5900
1	1.315	33.4	0.133	3.4	700	4800
			0.179	4.6	850	5900
			0.250	6.4	950	6500
1¼	1.660	42.2	0.140	3.6	1300	9000
			0.191	4.9	1900	13 100
			0.250	6.4	2000	13 800
1½	1.900	48.3	0.145	3.7	1300	9000
			0.200	5.1	1900	13 100
			0.281	7.1	2050	14 100

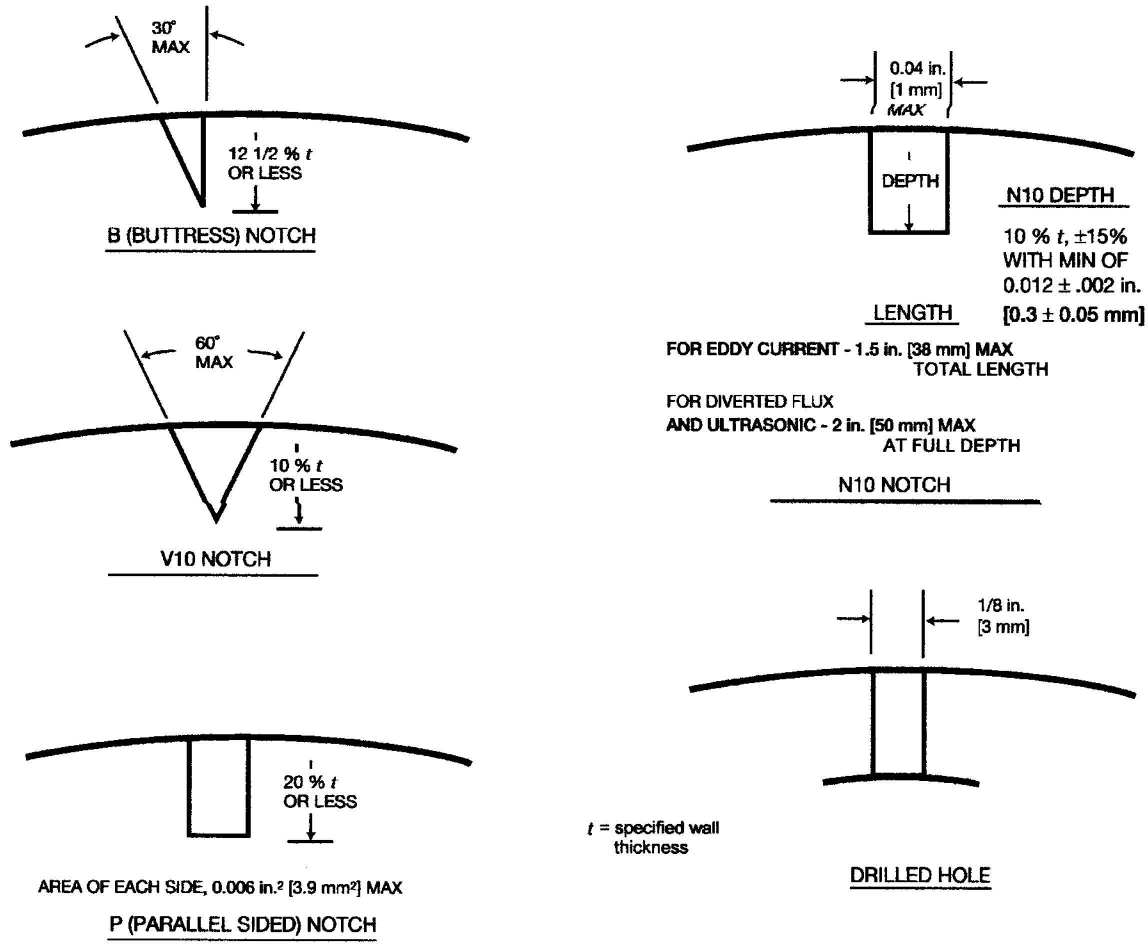

FIG. 1 Calibration Standards

TABLE 4 Acceptance Limits

Type of Notch	Size of Hole		Acceptance Limit Signal, %
	in.	mm	
N10, V10	⅛	3	100
B, P			80

B36.10M. The mass per unit length of pipe having an intermediate specified outside diameter, or intermediate specified wall thickness, or both, shall be calculated using the equation in 14.2.

14.2 *Mass*—The mass of a single length of pipe shall not vary more than +10 %, −5.0 % from its theoretical mass, as calculated using its mass per unit length and its measured length. Pipe masses per unit length not listed in ASME B36.10M shall be calculated using the following equation:

Inch-Pound Units:

$$M = t(D - t) \times 10.69 \quad (4)$$

SI Units:

$$M = t(D - t) \times 0.024\,66 \quad (5)$$

where:

M = mass per unit length, lb/ft [kg/m],
D = specified outside diameter, in. [mm], and
t = specified wall thickness, in. [mm].

14.3 *Wall Thickness*—The wall thickness at any point shall be not more than 12.5 % under the specified wall thickness.

14.4 *Length*—Unless otherwise agreed upon between the purchaser and the manufacturer, pipe shall be furnished in the nominal lengths and within the tolerances given in Table 5, as specified.

14.5 *Outside Diameter*—For pipe NPS 1½ [DN 40] and under, the outside diameter at any point shall not vary more than ± 1⁄64 in. [0.4 mm] from the specified outside diameter. For pipe NPS 2 [DN 50] and over, the outside diameter shall not vary more than ± 1 % from the specified outside diameter.

TABLE 5 Tolerance on Length

Nominal Length		Minimum Length		Minimum Average Length for Each Order Item		Maximum Length	
ft	m	ft	m	ft	m	ft	m
20	6	9.0	2.74	17.5	5.33	22.5	6.86
40	12	14.0	4.27	35.0	10.67	45.0	13.72
50	15	17.5	5.33	43.8	13.35	55.0	16.76

15. End Finish

15.1 Plain-end pipe shall be furnished with ends beveled to an angle of 30°, +5°, −0°, measured from a line drawn perpendicular to the axis of the pipe, and with a root face of 1⁄16 in. [1.6 mm] ± 1⁄32 in. [0.8 mm], or shall have another plain-end configuration, as specified in the purchase order.

15.2 Threaded-end pipe shall be furnished with threaded ends that are in accordance with the gaging practice and tolerances of API Standard 5B.

15.3 One end of each length of threaded-end pipe shall be provided with a coupling conforming to the requirements of API Specification 5L.

16. Workmanship, Finish and Appearance

16.1 Surface imperfections that penetrate more than 10 % of the specified wall thickness or encroach on the minimum permissible wall thickness shall be considered defects. Pipe with defects shall be given one of the following dispositions:

16.1.1 The section of the pipe containing the defect shall be cut off within the requirements for length.

16.1.2 The length shall be rejected.

16.2 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of a dispute, the measurement determined by the use of a mechanical caliper shall govern.

16.3 Repairs of the weld seam or pipe body, by welding, shall not be permitted.

16.4 Pipe shall be reasonably straight.

17. Certification

17.1 Where specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. Where specified in the purchase order or contract, a report of the test results shall be furnished.

18. Product Marking

18.1 Except as allowed by 18.2, each length of pipe shall be legibly marked to show the specification number, the name or brand of the manufacturer, FBW, the grade, the specified wall thickness, the specified outside diameter, the heat number or heat code, and the length. The length shall be marked in feet and tenths of a foot, or metres to two decimal places, whichever is applicable.

18.2 For bundled pipe NPS 1½ or smaller, it shall be permissible for the required markings to be included on a tag that is fastened securely to each bundle.

18.3 In addition to the requirements of 18.1 and 18.2, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order that a specific bar coding system be used.

19. Keywords

19.1 black steel pipe; furnace-butt-welded pipe; line pipe

Designation: A 1024/A 1024M – 02

Standard Specification for Steel Line Pipe, Black, Plain-End, Seamless[1]

This standard is issued under the fixed designation A 1024/A 1024M; 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 covers seamless, black, plain-end steel pipe for use in the conveyance of fluids under pressure. Pipe in sizes NPS 1 to 26, inclusive, as given in ASME B36.10M is included. Pipe having other dimensions, in this size range, may be furnished provided such pipe complies with all other requirements of this specification.

1.2 It is intended that the pipe be capable of being circumferentially welded in the field when welding procedures in accordance with the requirements of the applicable pipeline construction code are used.

1.3 The values stated in either inch-pound units or in SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values in each system are not exact equivalents; therefore, each system is to be used independently of the other.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy and Austenitic Alloy Steel Tubes[3]

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe[3]

A 751 Test Methods, Practices and Terminology for Chemical Analysis of Steel Products[2]

A 941 Terminology Related to Steel, Stainless Steel, Related Alloys, and Ferroalloys[3]

2.2 *API Standard:*

API RP 5L3 Recommended Practice for Conducting Drop-Weight Tear Tests on Line Pipe[4]

2.3 *ASME Standard:*

ASME B36.10M Welded and Seamless Wrought Steel Pipe[5]

3. Terminology

3.1 *Definitions*—For terminology used in this specification, refer to Terminology A 941.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *lot, n*—a quantity of pipe of the same ordered diameter, heat, wall thickness, and grade as given in Table 1.

3.2.2 *seamless pipe, n*—a tubular product made without a welded seam; it is manufactured usually by hot working the material, and if necessary, by subsequently cold-finishing the hot worked tubular product to produce the desired shape, dimensions, and properties.

3.2.3 *specified outside diameter (OD), n*—the outside diameter specified in the purchase order or the outside diameter listed in ASME B36.10M for the nominal pipe size specified in the purchase order.

4. General Requirements

4.1 Pipe furnished under this specification shall conform to the applicable requirements of Specification A 530/A 530M unless otherwise provided herein.

5. Ordering Information

5.1 Information items to be considered, if appropriate, for inclusion in the purchase order are as follows:

5.1.1 Specification designation and year of issue,

5.1.2 Quantity (feet or metres),

5.1.3 Grade (see Table 2 and 8.1.5),

5.1.4 Size (either nominal (NPS) or outside diameter and wall thickness),

5.1.5 Nominal length (see 14.3),

5.1.6 End finish (plain-end beveled or special, see 15.1),

5.1.7 Impact test temperature (see 8.2.5),

5.1.8 Heat treatment condition (see 6.1),

5.1.9 Carbon equivalent for over 0.800 in. [20.3 mm] wall thicknesses (see 7.4),

5.1.10 Reduced under thickness variation (see Table 5),

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved July 10, 2002. Published August 2002.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

[4] Available from The American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005.

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

TABLE 1 Lot Size and Sample Size for Mechanical and Toughness Testing

Pipe Size	Lot Size	Sample Size
<NPS 2	50 tons or fraction thereof	1
NPS 2 through NPS 5	400 lengths	1
NPS 6 through NPS 12	200 lengths	1
>NPS 12	100 lengths	1

TABLE 2 Tensile Requirements

Grade	Yield Strength, Min.		Yield Strength,[A] Max.		Tensile Strength, Min.	
	psi	MPa	psi	MPa	psi	MPa
35	35 000	240	65 000	450	60 000	415
50	50 000	345	77 000	530	70 000	485
60	60 000	415	80 000	550	75 000	515
70	70 000	485	87 000	600	80 000	550
80	80 000	550	97 000	670	90 000	620

[A] See 8.1.1.

TABLE 3 Hydrostatic Test Pressure

NPS Designator	Specified OD in. [mm]	Specified Wall Thickness in. [mm]	Test Pressure, Min. psi [kPa]
1	1.315 [33.4]	0.133 [3.4]	700 [4800]
		0.179 [4.6]	850 [5900]
		0.250 [6.4]	950 [6600]
		0.358 [9.1]	1000 [6900]
1¼	1.660 [42.2]	0.140 [3.6]	1300 [9000]
		0.191 [4.9]	1900 [13 100]
		0.250 [6.4]	2000 [13 800]
		0.382 [9.7]	2300 [15 900]
1½	1.900 [48.3]	0.145 [3.7]	1300 [9000]
		0.200 [5.1]	1900 [13 100]
		0.281 [7.1]	2000 [13 800]
		0.400 [10.2]	2300 [15 900]

TABLE 4 Acceptance Limits

Type of Notch	Acceptance Limit Signal, %
Parallel Sided Notch	100
Drilled Hole	100

TABLE 5 Permissible Variations in Wall Thickness

NPS Designator	Permissible Variations from Specified Wall Thickness,[A] %	
	Over	Under
1 to 2½, incl.	20.0	10.0
3 and larger	15.0	10.0

[A] If a reduced under thickness variation is specified in the purchase order, it is permissible for the over thickness variation to be increased, provided that the applicable total tolerance range in percent is not increased.

5.1.11 Special requirements,

5.1.12 Supplementary requirements, and

5.1.13 Bar coding (see 18.3).

6. Manufacture

6.1 Pipe shall be manufactured by the seamless process. Unless a specific heat treatment condition is specified in the purchase order, pipe shall be furnished in the as-rolled, normalized, normalized and tempered, or quenched and tempered condition.

7. Chemical Composition

7.1 The steel for any grade, by heat and product analyses, shall contain no more than 0.24 % carbon, 0.015 % sulfur, and 0.025 % phosphorus.

7.2 The steel shall contain no more than 0.0007 % boron, by heat analysis.

7.3 For pipe with a specified wall thickness less than or equal to 0.800 in. [20.3 mm], the carbon equivalent (CE) shall not exceed 0.43 %, calculated from the product analysis using the following equation:

$$CE = C + F\left[Mn/6 + Si/24 + Cu/15 + Ni/20 + (Cr+Mo+V+Cb)/5\right] \quad (1)$$

where:

F = a compliance factor that is dependent on the carbon content as shown below:

Carbon Content, %	F	Carbon Content, %	F
<0.06	0.53	0.15	0.88
0.06	0.54	0.16	0.92
0.07	0.56	0.17	0.94
0.08	0.58	0.18	0.96
0.09	0.62	0.19	0.97
0.10	0.66	0.20	0.98
0.11	0.70	0.21	0.99
0.12	0.75	>0.21	1.00
0.13	0.80		
0.14	0.85		

7.4 For pipe with a specified wall thickness greater than 0.800 in. [20.3 mm], the carbon equivalent (CE) shall be as specified in the purchase order.

7.5 A heat analysis shall be made for each heat of steel furnished under this specification. All pipe shall be marked with either a heat number or heat code in accordance with 18.1 and 18.2.

7.6 Product analyses shall be made on at least two samples from each heat of steel.

7.7 All analyses shall be in accordance with Test Methods, Practices, and Terminology A 751, and shall include all elements required in the carbon equivalent equation of 7.3, in addition to titanium, phosphorus, sulfur, and boron, except that the product analysis for boron is not required. Titanium is reported for information only and is not a cause for rejection.

7.8 If one or both of the product analyses representing a heat fail to conform to the specified requirements, the heat shall be rejected, or analyses shall be made on double the original number of test samples that failed, each of which shall conform to the specified requirements.

8. Mechanical Properties

8.1 *Tension Test*:

8.1.1 The material shall conform to the tensile requirements given in Table 2 and 8.1.6. The yield strength maxima apply only to pipe NPS 8 and larger.

8.1.2 The yield strength corresponding to a total extension under load of 0.5 % of the gage length shall be determined.

8.1.3 Transverse tension tests shall be performed on pipe NPS 8 and larger, or longitudinal, subject to approval by purchaser. Transverse test specimens shall be either strip test specimens or round bar test specimens, at the option of the manufacturer. All transverse strip test specimens shall be approximately 1½ in. [38 mm] wide in the gage length and each shall represent the full wall thickness of the pipe from which the test specimen was cut.

8.1.4 Longitudinal tension tests shall be performed on pipe smaller than NPS 8. Longitudinal test specimens shall be either strip test specimens, full-size test specimens, or round bar test specimens, at the option of the manufacturer.

8.1.5 Grades intermediate to those given in Table 2 shall be furnished if so specified in the purchase order. For intermediate grades, the difference between the specified maximum yield strength and the specified minimum yield strength and the difference between the specified minimum tensile strength and the specified minimum yield strength shall be as given in Table 2 for the next higher listed grade.

8.1.6 For each grade, the minimum elongation in 2 in. [50 mm] shall be as determined by the following equation:

$$e = C\,(A^{0.2} / U^{0.9}) \tag{2}$$

where:

e = minimum elongation in percent, rounded to the nearest percent,
C = constant = 625 000 [1940],
A = the lesser of 0.75 in.^{2} [485 mm^2] and the cross-sectional area of the tension test specimen in in.^{2}[mm^2], based upon the specified outside diameter of the pipe or the nominal width of the tension test specimen and the specified wall thickness, rounded to the nearest 0.01 in.^{2} [1 mm^2],
U = specified minimum tensile strength, psi [MPa].

8.2 *Impact Test*:

8.2.1 Except as allowed by 8.2.2, pipe shall be Charpy V-notch tested in accordance with Test Methods and Definitions A 370. For pipe smaller than NPS 5, such test specimens shall be taken longitudinal to the pipe axis. For pipe NPS 5 and larger, the test specimens shall be taken transverse to the pipe axis.

8.2.2 The basic test specimen is full size Charpy V-notch. Where full size test specimens, either conventional or containing the original OD surface, cannot be obtained due to a combination of specified outside diameter and specified wall thickness, two-thirds size or half-size test specimens shall be used. Where combinations of specified outside diameter and specified wall thickness do not permit half-size test specimens to be obtained, there is no requirement for impact testing. In all cases, the largest possible test specimen size shall be used, except where such a test specimen size will result in absorbed energy values greater than 80 % of the testing machine capacity.

8.2.3 When subsize test specimens are used, the requirements for absorbed energy shall be the adjusted values obtained by the following relationships, with the calculated values rounded to the nearest foot pound-force [joule]:

$$\text{For } 2/3 \text{ size: } N = R \times 0.67 \tag{3}$$
$$\text{For } 1/2 \text{ size: } N = R \times 0.50$$

where:

N = adjusted value, ft·lbf [J], and
R = value required by 8.2.4.

8.2.4 For pipe NPS 5 through NPS 26, the absorbed energy requirement for full size test specimens shall be 20 ft·lbf [27 J]. For pipe smaller than NPS 5, the absorbed energy requirement for full size test specimens shall be 30 ft·lbf [40 J].

8.2.5 Charpy impact testing shall be performed at 32°F [0°C], unless a lower test temperature is specified in the purchase order.

9. Hydrostatic Test

9.1 Each length of pipe shall be subjected to the hydrostatic test without leakage through the wall.

9.2 Each length of pipe NPS 2 or larger shall be tested, by the manufacturer, to a minimum hydrostatic pressure calculated from the following relationship:

$$\text{Inch-Pound Units: } P = 2\,(St/D) \times C \tag{4}$$
$$\text{SI Units: } P = 2000\,(St/D) \times C$$

where:

S = specified minimum yield strength, psi [MPa],
t = specified wall thickness, in. [mm],
D = specified outside diameter, in. [mm],
C = 0.60 for pipe NPS 2 through NPS 5,
0.75 for pipe larger than NPS 5 through NPS 8,
0.85 for pipe larger than NPS 8 through NPS 18,
0.90 for pipe larger than NPS 18, and
P = minimum hydrostatic test pressure, psi [kPa].

9.3 For pipe sizes smaller than NPS 2, the test pressures given in Table 3 are arbitrary. For pipe in sizes smaller than NPS 2 with specified wall thicknesses lighter than those listed, the test pressure for the next heavier listed specified wall thickness shall be used. For intermediate specified outside diameters for pipe sizes smaller than NPS 2, the test pressures given for the next smaller specified outside diameter shall be used.

9.4 When computed test pressures are not an exact multiple of 10 psi [100 kPa], they shall be rounded to the nearest 10 psi [100 kPa].

9.5 The minimum hydrostatic test pressure required to satisfy these requirements need not exceed 3000 psi [20 700 kPa]. This does not prohibit testing at a higher pressure at the manufacturer's option. The hydrostatic test pressure shall be maintained for not less than 5 s for all pipe sizes.

10. Nondestructive Electric Test

10.1 The entire outside surface of each pipe shall be inspected full length for longitudinal defects by either magnetic particle inspection, ultrasonic inspection, electromagnetic inspection, or a combination thereof. The location of the equipment in the mill shall be at the discretion of the manufacturer; however, the nondestructive inspection shall take place after all heat treating and expansion operations, if performed, but may take place before cropping, beveling, and end sizing.

10.2 *Magnetic Particle Inspection*—The depth of all imperfections revealed by magnetic particle inspection shall be determined; and when found to be greater than 10 % of the specified wall thickness, the imperfection shall be considered a defect.

10.3 *Ultrasonic and Electromagnetic Inspection*—Any equipment utilizing the ultrasonic or electromagnetic principles and capable of continuous and uninterrupted inspection shall be used. The equipment shall be checked with an applicable reference standard as described in 10.4 at least once every 8 h of inspection to demonstrate the effectiveness of the inspection procedures. The equipment shall be adjusted to produce well-defined indications when the reference standard is scanned by the inspection unit in a manner simulating the inspection of the product.

10.4 *Reference Standards*—Reference standards shall have both outside diameter and wall thickness within the tolerances specified for the production pipe to be inspected, and may be of any convenient length as determined by the pipe manufacturer. For ultrasonic inspection, the reference standard shall contain a machined notch as shown in Fig. 1. For electromagnetic inspection, the reference standard shall contain either a machined notch or a ⅛-in. [3-mm] drilled hole as shown in Fig. 1. The notch shall be in the outer surface of the reference standard and parallel to the longitudinal axis of the pipe or, at the option of the manufacturer, may be oriented at such an angle as to optimize the detection of anticipated defects. The ⅛-in. [3-mm] drilled hole shall be drilled radially through the wall of the reference standard.

NOTE 1—The calibration standards shown in Fig. 1 are convenient standards for the calibration of nondestructive equipment. The dimensions of such standards should not be construed as the minimum size imperfection detectable by such equipment.

10.5 *Acceptance Limits*—Table 4 gives the height of acceptance limit signals in percent of the height of signals produced by the calibration standards. Imperfections that produce a signal greater than the acceptance limit given in Table 4 shall be considered defects. Pipe containing defects shall be given one of the dispositions specified in 16.2.

10.6 Surface condition, operator qualification, extent of examination, and standardization procedure shall be in accordance with the provisions of Specification A 450/A 450M.

11. Number of Tests

11.1 Tension and impact testing shall be performed on a lot basis with the lot size and sample sizes as given in Table 1.

12. Test Methods

12.1 The test specimens and the tests required by this specification shall conform to those described in Test Methods and Definitions A 370.

13. Dimensions and Weights [Masses] Per Unit Length

13.1 The dimensions and weights [masses] per unit length of some of the pipe sizes included in this specification are given in ASME B36.10M. The weight [mass] per unit length of pipe having an intermediate diameter or specified wall thickness, or both, shall be calculated by the equation in 14.1.

14. Permissible Variations in Weight [Mass] and Dimensions

14.1 *Weight [Mass]*—The weight [mass] of a single length of pipe shall not vary more than +10 %, -3.5 % from its theoretical weight, as calculated using its weight [mass] per unit length and its measured length. Pipe weights [masses] per unit length not listed in ASME B36.10M shall be calculated from the following equation:

$$\text{Inch-Pound Units: } W = t(D-t) \times 10.69 \tag{5}$$
$$\text{SI Units: } W = t(D-t) \times 0.024\,66$$

where:
D = specified outside diameter, in. [mm],
t = specified wall thickness, in. [mm], and
W = weight [mass] per unit length, lb/ft [kg/m].

The weight [mass] of any order item shall not be more than 1.75 % under its theoretical weight [mass].

14.2 *Wall Thickness*—Variations in wall thickness shall not exceed those given in Table 5.

14.3 *Length*—Unless otherwise agreed upon between the purchaser and the manufacturer, pipe shall be furnished in the nominal lengths and within the permissible variations given in Table 6.

14.4 *Outside Diameter*—Pipe sizes NPS 20 and smaller shall permit the passage over the ends, for a distance of 4 in. [100 mm], of a ring gage that has a bore diameter no larger than the specified outside diameter plus the diameter plus tolerance. Outside diameter measurements of pipe larger than NPS 20 shall be made with a diameter tape. Outside diameter measurements, away from the ends, of pipe NPS 20 and smaller, shall be made with a snap gage, caliper, or other device that measures actual outside diameter in a single plane.

15. End Finish

15.1 Pipe furnished to this specification shall be plain-end beveled, with ends beveled to an angle of 30°, +5°, -0°, measured from a line drawn perpendicular to the axis of the

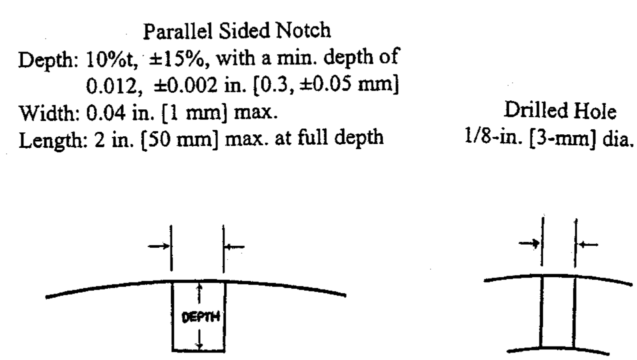

FIG. 1 Calibration Standards

TABLE 6 Permissible Variations in Length

Nominal Length		Minimum Length		Minimum Average Length for Each Order Item		Maximum Length	
ft	m	ft	m	ft	m	ft	m
20	6	9.0	3.00	17.5	5.00	22.5	7.00
40	12	14.0	4.00	35.0	11.00	45.0	14.00
50	15	17.5	5.00	43.8	14.00	55.0	17.00
60	18	21.0	6.00	52.5	16.00	65.0	20.00

pipe, and with a root face of 1⁄16-in. ± 1⁄32-in. [1.5 mm, +1.0, -0.5 mm], or another plain-end configuration as specified in the purchase order.

16. Workmanship, Finish and Appearance

16.1 Surface imperfections that are deeper than 10 % of the specified wall thickness shall be considered defects.

16.2 Pipe with defects shall be given one of the following dispositions:

16.2.1 The defect shall be removed by grinding, provided that a smooth curved surface remains and the remaining wall thickness is within specified limits.

NOTE 2—It is acceptable for the outside diameter at the point of grinding to be reduced by the amount so removed.

16.2.2 The section of the pipe containing the defect shall be cut off within the requirements for length.

16.2.3 The length shall be rejected.

16.3 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of a dispute, the measurement determined by the use of a mechanical caliper shall govern.

16.4 Repairs of the pipe body, by welding, are not permitted.

16.5 Pipe smaller than NPS 4 shall be reasonably straight. All other pipe sizes shall be randomly checked for straightness, and deviation from a straight line shall not exceed 0.2 % of the pipe length.

16.6 The pipe shall contain no dents greater than 10 % of the specified outside diameter or ¼ in. [6 mm], whichever is smaller, measured as the gap between the lowest point of the dent and a prolongation of the original contour of the pipe. Cold formed dents deeper than ⅛ in. [3 mm] shall be free of sharp bottom gouges. The gouges may be removed by grinding provided the remaining wall thickness is within specified limits. The length of the dent in any direction shall not exceed one half the pipe specified outside diameter.

17. Certification

17.1 A test report shall be furnished.

18. Product Marking

18.1 Except as allowed in 18.2, each length of pipe shall be marked legibly by painting to show the specification number; the name or brand of the manufacturer; the grade; the specified wall thickness; the specified outside diameter; the heat number or heat code; and the length. The length shall be marked in feet and tenths of a foot, or metres to two decimal places, whichever is applicable.

18.2 For bundled pipe NPS 1½ or smaller, the required markings may be included on a tag that is fastened securely to the bundle.

18.3 In addition to the requirements of 18.1 and 18.2, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order that a specific bar coding system be used.

19. Keywords

19.1 black steel pipe; line pipe; seamless

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified in the purchase order.

S1. Ductile Fracture Arrest

S1.1 Except as allowed by S1.2, one pipe per heat of steel shall be Charpy V-notch tested in accordance with Test Methods A 370 with the test specimens taken transverse to the pipe axis.

S1.2 The basic test specimen is full size Charpy V-notch. Where full size test specimens, either conventional or containing the original OD surface, cannot be obtained due to a combination of specified outside diameter and specified wall thickness, two-thirds size or half-size test specimens shall be used. Where combinations of specified outside diameter and specified wall thickness do not permit half-size test specimens to be obtained, there is no requirement for impact testing. In all cases, the largest possible test specimen size shall be used, except where such a test specimen size will result in absorbed energy values greater than 80 % of the testing machine capacity.

S1.3 When subsize test specimens are used, the requirements for absorbed energy shall be the adjusted values obtained by one of the following relationships, with the calculated values rounded to the nearest foot pound-force [joule]:

$$\text{For } 2/3 \text{ size: } N = R \times 0.67$$

$$\text{For } 1/2 \text{ size: } N = R \times 0.50$$

where:

N = adjusted value, ft·lbf [J], and

R = specified value required by S1.4.

S1.4 The absorbed energy requirement for full size specimens shall be the value claculated using the following equation, rounded to the nearest foot pound-force, or 30 ft·lbf [40 J], whichever is the greater:

$$V \text{ (full size)} = C \times D^{0.5} \times S^{1.5}$$

where:

D = specified outside diameter, in. [mm],
S = 0.72 × specified minimum yield strength, ksi [MPa],
C = constant 0.024 [0.000 36], and
V = minimum average value required, ft·lbf [J].

S1.5 The factor of 0.72 as shown in S1.4 may be increased by agreement between the purchaser and the manufacturer.

S1.6 Charpy impact testing shall be performed at 32°F [0°C], or lower as agreed upon between the purchaser and the manufacturer.

S1.7 Each Charpy impact test shall exhibit at least 70 % shear area average for the three specimens.

S2. Drop Weight Tear Testing

S2.1 The drop weight tear test shall be conducted in accordance with API RP 5L3.

S2.2 The temperature selected for conducting the drop weight tear test, the test frequency, and the criteria for acceptance shall be as specified in the purchase order.

Designation: A 1020/A 1020M – 02

Standard Specification for Steel Tubes, Carbon and Carbon Manganese, Fusion Welded, for Boiler, Superheater, Heat Exchanger and Condenser Applications[1]

This standard is issued under the fixed designation A 1020/A 1020M; 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 covers minimum wall thickness welded tubes made from carbon and carbon manganese steels listed in Table 1, with various grades intended for use in boiler, superheater, heat exchanger, or condenser applications.

1.2 The tubing sizes and thicknesses usually furnished to this specification are ¼ to 5 in. [6.3 to 127 mm] in outside diameter and 0.015 to 0.375 in. [0.4 to 9.5 mm], inclusive, in wall thickness. Tubing having other dimensions may be furnished provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

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 the specification is specified in the order.

1.5 Optional supplementary requirements are provided and when desired, shall be so stated on the purchase order.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes[2]

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing[3]

E 273 Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing[3]

TABLE 1 Chemical Requirements, Composition, %

Element	Grade A Low Carbon Steel	Grade C Medium Carbon Steel	Grade D Carbon Manganese Steel
Carbon	0.06–0.18	0.30 max	0.27 max
Manganese	0.27–0.63	0.80 max	1.00–1.50
Phosphorus	0.035 max	0.035 max	0.030 max
Sulfur	0.035 max	0.035 max	0.015 max
Silicon	No Requirement	No Requirement	0.10 min

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 (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 (product analysis, hydrostatic or nondestructive electric test, crush test, and bar coding).

3.1.7 Test report required (see Certification Section of Specification A 450/A 450M).

3.1.8 Specification designation.

3.1.9 Optional supplementary requirements are provided and when desired, shall be designated on the order.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 All steels shall be killed.

[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 A01.09 on Carbon Steel Tubular Products.

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[2] *Annual Book of ASTM Standards*, Vol 01.01.

[3] *Annual Book of ASTM Standards*, Vol 03.03.

5.2 The tubes shall be made by an automatic fusion welding process with no addition of filler metal.

6. Heat Treatment

6.1 After welding, all tubes shall be heat treated at a temperature of 1650°F [900°C] or higher and followed by cooling in air or in the cooling chamber of a controlled atmosphere furnace. Cold drawn tubes shall be heat treated after the final cold-draw pass at a temperature of 1200°F [650°C] or higher.

7. Chemical Composition

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

7.2 When a grade is ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed in Table 1 is not permitted.

8. Product Analysis

8.1 For the purpose of product analysis, a lot consists of 250 pieces for sizes up to and including 3 in. [76.2 mm] OD and 100 pieces for sizes over 3 in. [76.2 mm] OD; or when tubes are identified by heat number, all tubes within that heat.

8.2 When requested on the purchase order, a product analysis shall be made by the manufacturer or supplier from one tube per lot. The chemical composition thus determined shall conform to the requirements specified.

8.3 If the original test for product analysis fails, retest of two additional tubes per lot 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 producer, each tube may be individually tested for acceptance and those pieces that do not meet the requirements of the specification shall be rejected.

9. Tensile and Hardness Requirements

9.1 The term lot for tension and hardness tests applies to all tubes prior to cutting, of the same specified outside 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.

9.2 For Grade A tubes, hardness test shall be made on specimens from each of two tubes from each lot and shall not have a hardness number exceeding 72 HRB.

9.3 Grade C and D tubes, one tension test shall be made on specimens from each of two tubes from each lot and shall conform to properties prescribed in Table 2.

9.4 Table 3 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 shown above. The minimum elongation value shall be determined by the following equation:

TABLE 2 Tensile Requirements

	Grade C	Grade D
Tensile strength, min, ksi, [MPa]	60 [415]	70 [485]
Yield strength, min, ksi, [MPa]	37 [255]	40 [275]
Elongation in 2 in. or 50 mm, min %	30	30
For elongation 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 points shall be made.	1.50[A]	1.50[A]

[A] See Table 3 for the computed minimum values.

NOTE—For the purposes of design, the following tensile properties may be assumed for Grade A tubes:

Tensile strength, min, ksi, [MPa]	47 [325]
Yield strength, min, ksi, [MPa]	26 [180]
Elongation in 2 in. or 50 mm, min, %	35

TABLE 3 Minimum Elongation Values

Wall Thickness		Elongation in 2 in. or 50 mm, min, %[A]
in.	mm	
5⁄16 (0.312)	8	30
9⁄32 (0.281)	7.2	29
1⁄4 (0.250)	6.4	27
7⁄32 (0.219)	5.6	26
3⁄16 (0.188)	4.8	24
5⁄32 (0.156)	4	22
1⁄8 (0.125)	3.2	21
3⁄32 (0.094)	2.4	20
1⁄16 (0.062)	1.6	18

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

$$E = 48t + 15.00[E = 1.87t + 15.00]$$

where:

E = elongation in 2 in. or 50 mm, min, %, and

t = actual wall thickness of specimen, in. [mm].

10. Crush Test

10.1 Where specified in the purchase order, crushing tests shall be made. The test specimens shall be sections of tube having a length that is at least 2½ times the specified outside diameter of the tube for tubes that are less than 1 in. [25.4 mm] in specified outside diameter, and at least 2½ in. [63 mm] for tubes that are 1 in. [25.4 mm] or larger in specified outside diameter. Slight surface checks shall not be cause for rejection. The test specimens shall withstand crushing longitudinally without cracking, splitting, or opening at the weld, as follows:

Wall Thickness of Tubes, in. [mm]	Height of Crushed Section, in. [mm]	
	Grade A Tubes	Grades C and D Tubes
0.135 in. [3.4] and under	3⁄4 in. [19] or until outside folds are in contact	Crush tests not required
Over 0.135 in. [3.4]	1¼ [32]	

11. Mechanical Tests Required

11.1 For mechanical tests, a lot consists of 250 tubes for sizes up to and including 3 in. [76.2 mm] and 100 tubes for sizes over 3 in. [76.2 mm], or fraction thereof, prior to cutting.

11.2 *Flattening Tests*—One flattening test shall be made on specimens from each of two tubes from each lot or fraction thereof.

11.3 *Flange Test*:

11.3.1 For Grade A, one flange test shall be made on specimens from each of two tubes from each lot or fraction thereof.

11.3.2 For Grades C and D, one flange test shall be made on specimens from each of two tubes from each lot or fraction thereof. The width of the flange shall not be less than 75 % of that specified in specification A 450/A 450M.

11.4 *Crush Test*—For Grade A, where specified in the purchase order, one crush test shall be made on specimens from each of two tubes from each lot or fraction thereof.

11.5 *Reverse Flattening Test*—One reverse flattening test shall be made on each 1500 ft [450 m] of finished tubing.

12. Nondestructive Examination

12.1 *Hydrostatic or Nondestructive Electric Test*—Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

13. Surface Condition

13.1 The finished tubes shall be free of scale. A slight amount of oxidation shall not be considered as scale.

14. Forming Operations

14.1 When inserted in a boiler or heat exchanger, tubes shall be capable of withstanding expanding and beading without showing cracks or flaws, or opening at the weld. When properly manipulated, superheater tubes shall withstand all forging, welding, and bending operations necessary for applications without developing defects.

15. Product Marking

15.1 Marking shall be in accordance with Specification A 450/A 450M.

15.2 The manufacturer's name or symbol may be placed permanently on each tube by rolling or light stamping before normalizing. If a single stamp is placed on the tube by hand, this mark should not be less than 8 in. [200 mm] from one end of the tube.

15.3 *Bar Coding*—In addition to the requirements in 15.1 and 15.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

16. Keywords

16.1 automatic welded steel tube; boiler tube; carbon; steel tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become part of the specification when specified in the inquiry or invitation to bid, and production order or contract. These requirements shall not be considered unless specified in the order and the necessary tests shall be made at the mill.

S1. Additional Testing of Welded Tubing for ASME Requirements

S1.1 The weld seam of each tube shall be subjected to an ultrasonic inspection employing Practice E 273 or Practice E 213 with the rejection criteria referenced in Specification A 450/A 450M.

S1.2 If Practice E 273 is employed, a 100 % volumetric inspection of the entire length of each tube shall also be performed using one of the nondestructive electric tests permitted by Specification A 450/A 450M.

S1.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S1.4 In addition to the marking prescribed in Specification A 450/A 450M, "S1" shall be added after the grade designation.

Designation: A 1016/A 1016M – 04a

INTERNATIONAL

Standard Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes[1]

This standard is issued under the fixed designation A 1016/A 1016M; 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 covers a group of requirements that, unless otherwise specified in an individual specification, shall apply to the ASTM product specifications noted below.

Title of Specification	ASTM Designation[A]
Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes	A 209/A 209M
Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes	A 213/A 213M
Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes	A 249/A 249M
Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes	A 250/A 250M
Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service	A 268/A 268M
Seamless and Welded Austenitic Stainless Steel Tubing for General Service	A 269
Seamless and Welded Austenitic Stainless Steel Sanitary Tubing	A 270
Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service	A 334/A 334M
Welded Austenitic Stainless Steel Feedwater Heater Tubes	A 688/A 688M
Austenitic Stainless Steel Tubing for Breeder Reactor Core Components	A 771/A 771M
Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service	A 789/A 789M
Welded Ferritic Stainless Steel Feedwater Heater Tubes	A 803/A 803M
Austenitic and Ferritic Stainless Steel Duct Tubes for Breeder Reactor Core Components	A 826
High-Frequency Induction Welded, Unannealed Austenitic Steel Condenser Tubes	A 851

[A] These designations refer to the latest issue of the respective specifications.

1.2 In the case of conflict between a requirement of a product specification and a requirement of this general requirements specification, the product specification shall prevail. In the case of conflict between a requirement of the product specification or a requirement of this general requirements specification and a more stringent requirement of the purchase order, the purchase order shall prevail.

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 (SI) of the product specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 209/A 209M Specification for Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes

A 213/A 213M Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes

A 249/A 249M Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes

A 250/A 250M Specification for Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes

A 268/A 268M Specification for Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service

A 269 Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

A 270 Specification for Seamless and Welded Austenitic Stainless Steel Sanitary Tubing

A 334/A 334M Specification for Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 668/A 668M Specification for Welded Austenitic Stainless Steel Feedwater Heater Tubes

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 771/A 771M Specification for Seamless Austenitic and

[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 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.

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

Martensitic Stainless Steel Tubing for Liquid Metal-Cooled Reactor Core Components

A 789/A 789M Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service

A 803/A 803M Specification for Welded Ferritic Stainless Steel Feedwater Heater Tubes

A 826 Specification for Seamless Austenitic and Martensitic Stainless Steel Duct Tubes for Liquid Metal-Cooled Reactor Core Components[3]

A 851 Specification for High-Frequency Induction Welded, Unannealed Austenitic Steel Condenser Tubes[3]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

D 3951 Practice for Commercial Packaging

E 92 Test Method for Vickers Hardness of Metallic Materials

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing

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

E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys

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

2.2 *ASME Boiler and Pressure Vessel Code:*

Section IX, Welding Qualifications[4]

2.3 *Federal Standard:*

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products[5]

2.4 *Military Standards:*

MIL-STD-271 Nondestructive Testing Requirements for Metals[5]

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[5]

MIL-STD-792 Identification Marking Requirements for Special Purpose Equipment[5]

2.5 *Steel Structures Painting Council:*

SSPC-SP6 Surface Preparation Specification No.6 Commercial Blast Cleaning[6]

2.6 *Other Documents:*

SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification[7]

AIAG Bar Code Symbology Standard[8]

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Test Methods and Definitions A 370, Test Methods, Practices, and Terminology A 751, and Terminology A 941 are applicable to this specification and to those listed in 1.1.

3.1.2 *heat*, *n*—in secondary melting, all of the ingots remelted from a single primary heat.

3.1.3 *imperfection*, *n*—any discontinuity or irregularity found in a tube.

4. Manufacture

4.1 The steel shall made by any process.

4.2 The primary melting is permitted to incorporate separate degassing or refining and is permitted to be followed by secondary melting, such as electroslag remelting or vacuum-arc remelting.

4.3 When steel of different grades is sequentially strand cast, the resultant transition material shall be removed using an established procedure that positively separates the grades.

5. Ordering Information

5.1 It is the responsibility of the purchaser to specify all requirements that are necessary for product ordered under the product specification. Such requirements to be considered include, but are not limited to, the following:

5.1.1 Quantity (feet, metres, or number of pieces),

5.1.2 Name of material (stainless steel tubing),

5.1.3 Method of manufacture, when applicable (seamless (SML), welded (WLD), or heavily cold-worked (HCW)),

5.1.4 Grade or UNS number,

5.1.5 Size (outside diameter and average or minimum wall thickness),

5.1.6 Length (specific or random),

5.1.7 End finish if required,

5.1.8 Optional requirements,

5.1.9 Specific type of melting, if required,

5.1.10 Test report requirements,

5.1.11 Specification designation and year of issue, and

5.1.12 Special requirements or any supplementary requirements, or both.

6. Chemical Composition

6.1 *Chemical Analysis*—Samples for chemical analysis, and method of analysis, shall be in accordance with Test Methods, Practices, and Terminology A 751.

6.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall conform to the requirements specified in the product specification.

6.2.1 For steels ordered under product specifications referencing this specification of general requirements, the steel shall not contain an unspecified element, other than nitrogen for

[3] Withdrawn.

[4] Available from the ASME International Headquarters, Three Park Ave., New York, NY 10016–5990.

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, Attn: NPODS.

[6] Available from Steel Structures Painting Council, 40 24th St., 6th Floor, Pittsburgh, PA 15222–4656.

[7] Available from American Society for Nondestructive Testing, P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228–0518.

[8] Available from Automotive Industry Action Group, 26200 Lahser Rd., Suite 200, Southfield, MI 48034.

stainless steels, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation in a table of chemical requirements within any specification listed within the scope as being covered by this specification.

6.3 *Product Analysis*—Product analysis requirements and options, if any, shall be as contained in the product specification.

7. Tensile Properties

7.1 The material shall conform to the tensile property requirements prescribed in the individual product specification.

7.2 The yield strength, when specified, shall be determined corresponding to a permanent offset of 0.2 % of the gage length or to a total extension of 0.5 % of the gage length under load.

7.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than ¾ in. [19.0 mm] from the center of the gage length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

8. Standard Mass per Unit Length

8.1 The calculated mass per foot, based upon a specified minimum wall thickness, shall be determined by the following equation (see Note 1):

$$W = C(D–t)t \tag{1}$$

where:

C = 10.69 [0.0246615],
W = mass per unit length, lb/ft [kg/m],
D = specified outside diameter, in. [mm], and
t = specified minimum wall thickness, in. [mm].

NOTE 1—The calculated masses given by Eq 1 are based on the masses for carbon steel tubing. The mass of tubing made of ferritic stainless steels may be up to about 5 % less, and that made of austenitic stainless steel up to about 2 % greater than the values given. Mass of ferritic/austenitic (duplex) stainless steel will be intermediate to the mass of fully austenitic and fully ferritic stainless steel tubing.

8.2 The permitted variations from the calculated mass per foot [kilogram per meter] shall be as prescribed in Table 1.

9. Permitted Variations in Wall Thickness

9.1 Variations from the specified minimum wall thickness shall not exceed the amounts prescribed in Table 2.

TABLE 1 Permitted Variations in Mass Per Foot[A]

Method of Manufacture	Permitted Variation in Mass per Foot, %	
	Over	Under
Seamless, hot-finished	16	0
Seamless, cold-finished		
1½ in. [38 mm] and under OD	12	0
Over 1½ in. [38 mm] OD	13	0
Welded	10	0

[A] These permitted variations in mass apply to lots of 50 tubes or more in sizes 4 in. [101.6 mm] and under in outside diameter, and to lots of 20 tubes or more in sizes over 4 in. [101.6 mm] in outside diameter.

TABLE 2 Permitted Variations in Wall Thickness[A]

Outside Diameter in. [mm]	Wall Thickness, %: 0.095 [2.4] and Under		Over 0.095 to 0.150 [2.4 to 3.8], incl		Over 0.150 to 0.0180 [3.8 to 4.6], incl		Over 0.180 [4.6]	
	Over	Under	Over	Under	Over	Under	Over	Under
Seamless, Hot-Finished Tubes								
4 [100] and under	40	0	35	0	33	0	28	0
Over 4 [100]	. . .	. . .	35	0	33	0	28	0
Seamless, Cold-Finished Tubes								
			Over	Under				
1½ [38.1] and under			20	0				
Over 1½ [38.1]			22	0				
Welded Tubes								
All sizes			18	0				

[A] These permitted variations in wall thickness apply only to tubes, except internal-upset tubes, as rolled or cold-finished, and before swaging, expanding, bending, polishing, or other fabricating operations.

9.2 For tubes 2 in. [50 mm] and over in outside diameter and 0.220 in. [5.6 mm] and over in thickness, the variation in wall thickness in any one cross section of any one tube shall not exceed the following percentage of the actual mean wall at the section. The actual mean wall is defined as the average of the thickest and thinnest wall in that section.

Seamless tubes ±10 %
Welded tubes ±5 %

9.3 When cold-finished tubes as ordered require wall thicknesses ¾ in. [19.1 mm] or over, or an inside diameter 60 % or less of the outside diameter, the permitted variations in wall thickness for hot-finished tubes shall apply.

10. Permitted Variations in Outside Diameter

10.1 Except as provided in 10.2.1, 10.3, and 25.10.4, variations from the specified outside diameter shall not exceed the amounts prescribed in Table 3.

TABLE 3 Permitted Variations in Outside Diameter[A]

Specified Outside Diameter, in. [mm]	Permitted Variations, in. [mm] Over	Under
Hot-Finished Seamless Tubes		
4 [100] or under	1/64 [0.4]	1/32 [0.8]
Over 4 to 7½ [100 to 200], incl	1/64 [0.4]	3/64 [1.2]
Over 7½ to 9 [200 to 225], incl	1/64 [0.4]	1/16 [1.6]
Welded Tubes and Cold-Finished Seamless Tubes		
Under 1 [25]	0.004 [0.1]	0.004 [0.11]
1 to 1½ [25 to 40], incl	0.006 [0.15]	0.006 [0.15]
Over 1½ to 2 [40 to 50], excl	0.008 [0.2]	0.008 [0.2]
2 to 2½ [50 to 65], excl	0.010 [0.25]	0.010 [0.25]
2½ to 3 [65 to 75], excl	0.012 [0.3]	0.012 [0.3]
3 to 4 [75 to 100], incl	0.015 [0.38]	0.015 [0.38]
Over 4 to 7½ [100 to 200], incl	0.015 [0.38]	0.025 [0.64]
Over 7½ to 9 [200 to 225], incl	0.015 [0.38]	0.045 [1.14]

[A] Except as provided in 10.2 and 10.3, these permitted variations include out-of-roundness. These permitted variations in outside diameter apply to hot-finished seamless, welded and cold-finished seamless tubes before other fabricating operations such as upsetting, swaging, expanding, bending, or polishing.

10.2 Thin-wall tubes usually develop significant ovality (out-of-roundness) during final annealing, or straightening, or both. Thin-wall tubes are defined as those with a specified wall 3 % or less than the specified OD, or with a wall specified as 0.020 in. [0.5 mm] or less.

10.2.1 1 The diameter tolerances of Table 3 are not sufficient to provide for additional ovality expected in thin-wall tubes, and, for such tubes, are applicable only to the mean of the extreme (maximum and minimum) outside diameter readings in any one cross section. However, for thin wall tubes the difference in extreme outside diameter readings (ovality) in any one cross section shall not exceed the following ovality allowances:

Outside Diameter, in. [mm]	Ovality Allowance
1 [25.4] and under	0.020 [0.5]
Over 1 [25.4]	2.0 % of specified outside diameter

10.3 For cold-finished seamless austenitic and ferritic/austenitic tubes, an ovality allowance is necessary for all sizes less than 2 in. [50.8 mm] outside diameter, because they are likely to become out of round during their final heat treatment. For such tubes, the maximum and minimum outside diameter at any cross section shall not deviate from the nominal diameter by more than ±0.010 in. [±0.25 mm]. However, the mean diameter at that cross section must still be within the given permitted variation given in Table 3. In the event of conflict between the provisions of 10.2.1 and those of 10.3, the larger value of ovality tolerance shall apply.

10.4 When the specified wall is 2 % or less of the specified OD, the method of measurement is per agreement between purchaser and manufacturer (see Note 2).

NOTE 2—Very thin wall tubing may not be stiff enough for the outside diameter to be accurately measured with a point contact method, such as with the use of a micrometer or caliper. When very thin walls are specified, “go” – “no go” ring gages are commonly used to measure diameters of 1½ in. [38.1 mm] or less. A .002 in. [0.05 mm] additional tolerance is usually added on the “go” ring gage to allow clearance for sliding. On larger diameters, measurement is commonly performed with a pi tape. Other methods, such as optical methods, may also be considered.

11. Permitted Variations in Length

11.1 Variations from the specified length shall not exceed the amounts prescribed in Table 4.

12. Permitted Variations in Height of Flash on Electric-Resistance-Welded Tubes

12.1 For tubes over 2 in. [50.8 mm] in outside diameter, or over 0.135 in. [3.44 mm] in wall thickness, the flash on the inside of the tubes shall be mechanically removed by cutting to a maximum height of 0.010 in. [0.25 mm] at any point on the tube.

12.2 For tubes 2 in. [50.8 mm] and under in outside diameter and 0.135 in. [3.44 mm] and under in wall thickness, the flash on the inside of the tube shall be mechanically removed by cutting to a maximum height of 0.006 in. [0.15 mm] at any point on the tube.

TABLE 4 Permitted Variations in Length[A]

Method of Manufacture	Specified Outside Diameter, in. [mm]	Cut Length, in. [mm] Over	Under
Seamless, hot-finished	All sizes	3⁄16 [5]	0 [0]
Seamless, cold-finished	Under 2 [50.8]	1⁄8 [3]	0 [0]
	2 [50.8] or over	3⁄16 [5]	0 [0]
Welded	Under 2 [50.8]	1⁄8 [3]	0 [0]
	2 [50.8] or over	3⁄16 [5]	0 [0]

[A] These permitted variations in length apply to tubes before bending. They apply to cut lengths up to and including 24 ft [7.3 m]. For lengths greater than 24 ft [7.3 m], the above over-tolerances shall be increased by 1⁄8 in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft or ½ in. [13 mm], whichever is the lesser.

13. Straightness and Finish

13.1 Finished tubes shall be reasonably straight and have smooth ends free of burrs. They shall have a workmanlike finish. It is permitted to remove surface imperfections by grinding, provided that a smooth curved surface is maintained, and the wall thickness is not decreased to less than that permitted by this or the product specification, or the purchase order. The outside diameter at the point of grinding may be reduced by the amount so removed.

14. Repair by Welding

14.1 Repair welding of base metal defects in tubing is permitted only with the approval of the purchaser and with the further understanding that the tube shall be marked “WR” and the composition of the deposited filler metal shall be suitable for the composition being welded. Defects shall be thoroughly chipped or ground out before welding and each repaired length shall be reheat treated or stress relieved as required by the applicable specification. Each length of repaired tube shall be examined by a nondestructive test as required by the product specification.

14.2 Repair welding shall be performed using procedures and welders or welding operators that have been qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

15. Retests

15.1 If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional tubes of double the original number from the same group or lot, each of which shall conform to the requirements specified.

16. Reheat Treatment

16.1 If the individual tubes or the tubes selected to represent any group or lot fail to conform to the test requirements, the individual tubes or the group or lot represented may be reheat treated and resubmitted for test. Not more than two reheat treatments shall be permitted.

17. Test Specimens

17.1 Test specimens shall be taken from the ends of finished tubes prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free of burrs and flaws.

17.2 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

18. Method of Mechanical Testing

18.1 The specimens and mechanical tests required shall be made in accordance with Test Methods and Definitions A 370.

18.2 Specimens shall be tested at room temperature.

18.3 Small or subsize specimens as described in Test Methods and Definitions A 370 may be used only when there is insufficient material to prepare one of the standard specimens. When using small or subsize specimens, the largest one possible shall be used.

19. Flattening Test

19.1 A section of tube not less than 2½ in. [60 mm] in length for seamless tubes and not less than 4 in. [100 mm] in length for welded tubes and for heavily cold-worked tubes shall be flattened cold between parallel plates in two steps. For welded tubes, the weld shall be placed 90° from the direction of the applied force (at a point of maximum bending). During the first step, which is a test for ductility, no cracks or breaks, except as provided for in 19.4, on the inside, outside, or end surfaces shall occur in seamless tubes, or on the inside or outside surfaces of welded tubes and heavily cold-worked tubes, until the distance between the plates is less than the value of H calculated by the following equation:

$$H = \frac{(1 + e)t}{e + t/D} \tag{2}$$

where:

H = distance between flattening plates, in. [mm],
t = specified wall thickness of the tube, in. [mm],
D = specified outside diameter of the tube, in. [mm], and
e = deformation per unit length (constant for a given grade of steel: 0.07 for medium-carbon steel (maximum specified carbon 0.19 % or greater), 0.08 for ferritic alloy steel, 0.09 for austenitic steel, and 0.09 for low-carbon steel (maximum specified carbon 0.18 % or less)).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the specimen meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

19.2 Surface imperfections in the test specimens before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

19.3 Superficial ruptures resulting from surface imperfections shall not be cause for rejection.

19.4 When low D-to-t ratio tubular products are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than 10.

20. Reverse Flattening Test

20.1 A section 4 in. [100 mm] in length of finished welded tubing in sizes down to and including ½ in. [12.7 mm] in outside diameter shall be split longitudinally 90° on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There shall be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

21. Reverse Bend Test

21.1 A section 4 in. [100 mm] minimum in length shall be split longitudinally 90° on each side of the weld. The sample shall then be opened and bent around a mandrel with a maximum thickness of four times the wall thickness, with the mandrel parallel to the weld and against the original outside surface of the tube. The weld shall be at the point of maximum bend. There shall be no evidence of cracks or of overlaps resulting from the reduction in thickness of the weld area by cold working. When the geometry or size of the tubing make it difficult to test the sample as a single piece, the sample may be sectioned into smaller pieces provided a minimum of 4 in. of weld is subjected to reverse bending.

21.2 The reverse bend test is not applicable when the wall is 10 % or more of the specified outside diameter, or the wall thickness is 0.134 in. [3.4 mm] or greater, or the outside diameter is less than 0.375 in. [9.5 mm]. Under these conditions, the reverse flattening test shall apply.

22. Flaring Test

22.1 A section of tube approximately 4 in. [100 mm] in length shall stand being flared with a tool having a 60° included angle until the tube at the mouth of the flare has been expanded to the percentages specified in Table 5 without cracking or showing imperfections rejectable under the provisions of the product specification.

23. Flange Test

23.1 A section of tube shall be capable of having a flange turned over at a right angle to the body of the tube without cracking or showing imperfections rejectable under the provisions of the product specification. The width of the flange for carbon and alloy steels shall be not less than the percentages specified in Table 6. For the austenitic grades, the width of the flange for all sizes listed in Table 6 shall be not less than 15 %.

24. Hardness Test

24.1 For tubes with wall thickness 0.200 in. [5.1 mm] or over, either the Brinell or Rockwell hardness test shall be used. When Brinell hardness testing is used, a 10-mm ball with 3000, 1500, or 500-kg load, or a 5-mm ball with 750-kg load shall be used, at the option of the manufacturer.

24.2 For tubes 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.

TABLE 5 Flaring Test Requirements

Ratio of Inside Diameter to Specified Outside Diameter[A]	Minimum Expansion of Inside Diameter, %	
	Carbon, Carbon-Molybdenum, and Other Ferritic Alloy Steels	Austenitic Steels
0.9	21	15
0.8	22	17
0.7	25	19
0.6	30	23
0.5	39	28
0.4	51	38
0.3	68	50

[A] In determining the ratio of inside diameter to specified outside diameter, the inside diameter shall be defined as the actual mean inside diameter of the material tested.

TABLE 6 Flange Requirements

Specified Outside Diameter of Tube, in. [mm]	Width of Flange
To 2½ [63.5], incl	15 % of Specified Outside Diameter
Over 2½ to 3¾ [63.5 to 95.2], incl	12½ % of Specified Outside Diameter
Over 3¾ to 8 [95.2 to 203.2], incl	10 % of Specified Outside Diameter

24.3 For tubes with wall thickness less than 0.065 in. [1.7 mm], the hardness test shall not be required.

24.4 The Brinell hardness test shall, at the option of the manufacturer, be made on the outside of the tube near the end, on the outside of a specimen cut from the tube, or on the wall cross section of a specimen cut from the tube. This test shall be made so that the distance from the center of the impression to the edge of the specimen is at least 2.5 times the diameter of the impression.

24.5 The Rockwell hardness test shall, at the option of the manufacturer, be made on the inside surface, on the wall cross section, or on a flat on the outside surface.

24.6 For tubes furnished with upset, swaged, or otherwise formed ends, the hardness test shall be made as prescribed in 24.1 and 24.2 on the outside of the tube near the end after the forming operation and heat treatment.

24.7 For welded or brazed tubes, the hardness test shall be made away from the joints.

24.8 When the product specification provides for Vickers hardness, such testing shall be in accordance with Test Method E 92.

25. Nondestructive Examination

25.1 Except as provided in 26.1, each tube shall be examined by a nondestructive examination method in accordance with Practice E 213, Practice E 309 (for ferromagnetic materials), Practice E 426 (for non-magnetic materials), or Practice E 570. Upon agreement, Practice E 273 shall be employed in addition to one of the full periphery tests. The range of tube sizes that may be examined by each method shall be subject to the limitations in the scope of that practice. In case of conflict between these methods and practices and this specification, the requirements of this specification shall prevail.

25.2 The following information is for the benefit of the user of this specification.

25.2.1 Calibration standards for the nondestructive electric test are convenient standards for calibration of nondestructive testing equipment only. For several reasons, including shape, orientation, width, and so forth, the correlation between the signal produced in the electric test from an imperfection and from calibration standards is only approximate. A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

25.2.2 The ultrasonic examination referred to in this specification is intended to detect longitudinal discontinuities having a reflective area similar to or larger than the calibration reference notches specified in 25.8. The examination may not detect circumferentially oriented imperfections or short, deep defects.

25.2.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type. Practices E 309 and E 426 contain additional information regarding the capabilities and limitations of eddy-current examination.

25.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. The provisions of this specification only provide for longitudinal calibration for flux leakage. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

25.2.5 The hydrostatic test referred to in Section 25 is a test method provided for in many product specifications. This test has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall defects or defects that extend an appreciable distance into the wall without complete penetration.

25.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular products.

25.3 *Time of Examination*—Nondestructive examination for specification acceptance shall be performed after all deformation processing, heat treating, welding, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

25.4 *Surface Condition*:

25.4.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

25.4.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

25.5 *Extent of Examination*:

25.5.1 The relative motion of the tube and the transducer(s), coil(s), or sensor(s) shall be such that the entire tube surface is scanned, except for end effects as noted in 24.5.2.

25.5.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

25.6 *Operator Qualifications*:

25.6.1 The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent documented standard agreeable to both purchaser and manufacturer.

25.7 *Test Conditions*:

25.7.1 For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.0 MHz, and the maximum transducer size shall be 1.5 in. [38 mm].

25.7.2 For eddy current testing, the excitation coil frequency shall be chosen to ensure adequate penetration, yet provide good signal-to-noise ratio.

25.7.2.1 The maximum coil frequency shall be:

Specified Wall Thickness, in. [mm]	Maximum Frequency, kHz
<0.050 in. [1.25]	100
0.050 to 0.150 [1.25 to 3.80]	50
>0.150 [3.80]	10

25.8 *Reference Standards*:

25.8.1 Reference standards of convenient length shall be prepared from a length of tube of the same grade, specified size (outside diameter and wall thickness), surface finish, and heat treatment condition as the tubing to be examined.

25.8.2 For eddy current testing, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

25.8.2.1 *Drilled Hole*—The reference standard shall contain three or more holes, equally spaced circumferentially around the tube and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the tube wall, with care being taken to avoid distortion of the tube while drilling. The holes shall not be larger than 0.031 in. [0.8 mm] in diameter. As an alternative, the producer may choose to drill one hole and run the calibration standard through the test coil three times, rotating the tube approximately 120° each time. More passes with smaller angular increments may be used, provided testing of the full 360° of the coil is obtained. For welded tubing, if the weld is visible, one of the multiple holes or the single hole shall be drilled in the weld.

25.8.2.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼ in. [6.4 mm] diameter, a notch shall be milled or filed tangential to the surface and transverse to the longitudinal axis of the tube. Said notch shall have a depth not exceeding 12.5 % of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater.

25.8.2.3 *Longitudinal Notch*—A notch 0.031 in. (0.8 mm) or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding 12.5 % of the specified wall thickness of the tube or 0.004 in. (0.1 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

25.8.3 *For ultrasonic testing*, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of the notches shall not exceed 12.5 % of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater. The width of the notch shall not exceed two times the depth. For welded tubing, the notches shall be placed in the weld, if the weld is visible.

25.8.4 *For flux leakage testing*, the longitudinal reference notches shall be straight-sided notches machined in a radial plane parallel to the tube axis on the inside and outside surfaces of the tube. Notch depth shall not exceed 12.5 % of the specified wall thickness or 0.004 in. [0.1 mm], whichever is greater. Notch length shall not exceed 1 in. [25.4 mm], and the width shall not exceed the depth. Outside and inside notches shall have sufficient separation to allow distinct identification of the signal from each notch.

25.8.5 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

25.9 *Standardization Procedure*:

25.9.1 The test apparatus shall be standardized at the beginning and end of each series of tubes of the same specified size (diameter and wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h during the examination of such tubing. More frequent standardizations may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

25.9.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss or shutdown.

25.9.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the tube to be tested, except that, at the manufacturer's discretion, the tubes may be tested at a higher sensitivity.

25.9.4 The signal-to-noise ratio for the reference standard shall be 2.5:1 or greater, and the reference signal amplitude for each discontinuity shall be at least 50 % of full scale of the display. In establishing the noise level, extraneous signals from identifiable surface imperfections on the reference standard may be ignored. When reject filtering is used during UT testing, linearity must be demonstrated.

25.9.5 If, upon any standardization, the reference signal amplitude has decreased by at least 29 % (3.0 dB), the test apparatus shall be considered out of standardization. The test system settings may be changed, or the transducer(s), coil(s), or sensor(s) adjusted, and the unit restandardized, but all tubes tested since the last acceptable standardization must be retested.

25.10 *Evaluation of Imperfections*:

25.10.1 Tubing producing a test signal equal to or greater than the lowest signal produced by the reference standard shall be designated suspect, shall be clearly marked or identified, and shall be separated from the acceptable tubing.

25.10.2 Such suspect tubing shall be subject to one of the following three dispositions:

25.10.2.1 The tubes shall be rejected without further examination, at the discretion of the manufacturer.

25.10.2.2 If the test signal was produced by imperfections such as scratches, surface roughness, dings, straightener marks, loose ID bead and cutting chips, steel die stamps, stop marks, tube reducer ripple, or chattered flash trim, the tubing shall be accepted or rejected depending on visual observation of the severity of the imperfection, the type of signal it produces on the testing equipment used, or both.

25.10.2.3 If the test signal was produced by imperfections that cannot be identified, or was produced by cracks or crack-like imperfections, the tubing shall be rejected.

25.10.3 Any tubes with imperfections of the types in 25.10.2.2 and 25.10.2.3, exceeding 0.004 in. [0.1 mm] or 12.5 % of the specified minimum wall thickness (whichever is greater) in depth shall be rejected.

25.10.4 Rejected tubes may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. If grinding is performed, the outside diameter in the area of grinding may be reduced by the amount so removed. To be accepted, reconditioned tubes must pass the nondestructive examination by which they were originally rejected.

26. Hydrostatic Test

26.1 In lieu of nondestructive electric examination, and when specified by the purchaser, and, except as provided in 26.2 and 26.3, each tube shall be tested by the manufacturer to a minimum hydrostatic test pressure determined by the following equation:

$$\text{Inch-Pound Units: } P = 32000\ t/D \quad (3)$$

$$\text{SI Units: } P = 220.6\ t/D$$

where:

P = hydrostatic test pressure, psi or MPa,
t = specified wall thickness, in. or mm, and
D = specified outside diameter, in. or mm.

26.1.1 The hydrostatic test pressure determined by Eq 3 shall be rounded to the nearest 50 psi [0.5 MPa] for pressure below 1000 psi [7 MPa], and to the nearest 100 psi [1 MPa] for pressures 1000 psi [7 MPa] and above. The hydrostatic test may be performed prior to cutting to final length, or prior to upsetting, swaging, expanding, bending or other forming operations, or both.

26.2 Regardless of the determination made by Eq 3, the minimum hydrostatic test pressure required to satisfy these requirements need not exceed 1000 psi [7 MPa]. This does not prohibit testing at higher pressures at manufacturer's option or as provided in 26.3.

26.3 With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements of 26.2 or 26.1, or both, may be stated on the order. The tube wall stress shall be determined by the following equation:

$$S = PD/2t \quad (4)$$

where:

S = tube wall stress, psi or MPa, and all other symbols as defined in 24.1.

26.4 The test pressure shall be held for a minimum of 5 s.

26.5 If any tube shows leaks during the hydrostatic test, it shall be rejected.

26.6 The hydrostatic test may not be capable of testing the end portion of the pipe. The lengths of pipe that cannot be tested shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

27. Air Underwater Pressure Test

27.1 When this test is required, each tube, with internal surface clean and dry, shall be internally pressurized to 150 psi [1000 kPa] minimum with clean and dry compressed air while being submerged in clear water. The tube shall be well lighted, preferably by underwater illumination. Any evidence of air leakage of the pneumatic couplings shall be corrected prior to testing. Inspection shall be made of the entire external surface of the tube after holding the pressure for not less than 5 s after the surface of the water has become calm. If any tube shows leakage during the air underwater test, it shall be rejected. Any leaking areas may be cut out and the tube retested.

28. Certification and Test Reports

28.1 The producer or supplier shall furnish a certificate of compliance stating that the material was manufactured, sampled, tested, and inspected in accordance with the specification, including year date, the supplementary requirements, and any other requirements designated in the purchase order or contract, and the results met the requirements of that specification, the supplementary requirements and the other requirements. A signature or notarization is not required on the certificate of compliance, but the document shall be dated and shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature or notarization, the certifying organization is responsible for the contents of the document.

28.2 In addition to the certificate of compliance, the manufacturer shall furnish test reports that include the following information and test results, where applicable:

28.2.1 Heat number,

28.2.2 Heat analysis,

28.2.3 Product analysis, when specified,

28.2.4 Tensile properties,

28.2.5 Width of the gage length, when longitudinal strip tension test specimens are used,

28.2.6 Flattening test acceptable,

28.2.7 Reverse flattening test acceptable,

28.2.8 Flaring test acceptable,

28.2.9 Flange test acceptable,

28.2.10 Hardness test values,

28.2.11 Hydrostatic test pressure,

28.2.12 Nondestructive electric test method,

28.2.13 Impact test results, and

28.2.14 Any other test results or information required to be reported by the product specification or the purchase order or contract.

28.3 The manufacturer shall report, along with the test report or in a separate document, any other information that is required to be reported by the product specification or the purchase order or contract.

28.4 The certificate of compliance shall include a statement of explanation for the letter added to the specification number marked on the tubes (see 30.3) when all of the requirements of the specification have not been completed. The purchaser must certify that all requirements of the specification have been completed before the removal of the letter (that is, X, Y, or Z).

28.5 A test report, certificate of compliance, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

29. Inspection

29.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to be satisfied that the product is being produced and furnished in accordance with the ordered product specification. Mill inspection by the purchaser shall not interfere with the manufacturer's operations.

30. Rejection

30.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the ordered product specification based on the inspection and test method as outlined in the ordered product specification, the length shall be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

30.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such material shall be a matter for agreement.

31. Product Marking

31.1 Each length of tube shall be legibly stenciled with the manufacturer's name or brand, the specification number, and grade. The marking need not include the year of issue of the specification. For tubes less than 1¼ in. [31.8 mm] in diameter and tubes under 3 ft [1 m] in length, the required information may be marked on a tag securely attached to the bundle or box in which the tubes are shipped.

31.2 For austenitic steel pipe, the marking paint or ink shall not contain detrimental amounts of harmful metals, or metal salts, such as zinc, lead, or copper, which cause corrosive attack on heating.

31.3 When it is specified that certain requirements of a specification adopted by the ASME Boiler and Pressure Vessel Committee are to be completed by the purchaser upon receipt of the material, the manufacturer shall indicate that all requirements of the specification have not been completed by a letter such as X, Y, or Z, immediately following the specification number. This letter may be removed after completion of all requirements in accordance with the specification. An explanation of specification requirements to be completed is provided in 28.4.

31.4 *Bar Coding*—In addition to the requirements in 31.1-31.3, the manufacturer shall have the option of using bar coding as a supplementary identification method. Bar coding should be consistent with the (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

32. Packaging, Marking, and Loading

32.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with the procedures of Practices A 700.

33. Government Procurement

33.1 *Scale Free Tube*:

33.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order, for agencies of the U.S. Government where scale-free tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

33.1.2 Tube shall be ordered to outside diameter (OD) and wall thickness.

33.1.3 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility for ensuring that all products or supplies submitted to the government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the government to accept the material. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to the prescribed requirements.

33.1.4 *Sampling for Flattening and Flaring Test and for Visual and Dimensional Examination*—Minimum sampling for flattening and flaring tests and visual and dimensional examination shall be as follows:

Lot Size (pieces per lot)	Sample Size
2 to 8	Entire lot
9 to 90	8
91 to 150	12
151 to 280	19
281 to 500	21
501 to 1200	27
1201 to 3200	35
3201 to 10 000	38
10 001 to 35 000	46

In all cases, the acceptance number is zero and the rejection number is one. Rejected lots may be screened and resubmitted for visual and dimensional examination. All defective items shall be replaced with acceptable items prior to lot acceptance.

33.1.5 *Sampling for Chemical Analysis*—One sample for chemical analysis shall be selected from each of two tubes chosen from each lot. A lot shall be all material poured from one heat.

33.1.6 *Sampling for Tension and Bend Test*—One sample shall be taken from each lot. A lot shall consist of all tube of the same outside diameter and wall thickness manufactured during an 8-h shift from the same heat of steel, and heat treated under the same conditions of temperature and time in a single charge in a batch type furnace, or heat treated under the same condition in a continuous furnace, and presented for inspection at the same time.

33.1.7 *Hydrostatic and Ultrasonic Tests*—Each tube shall be tested by the ultrasonic (when specified) and hydrostatic tests.

33.1.8 Tube shall be free from heavy oxide or scale. The internal surface of hot finished ferritic steel tube shall be pickled or blast cleaned to a free of scale condition equivalent to the CSa2 visual standard listed in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

33.1.9 In addition to the marking in Specification A 530/A 530M, each length of tube ¼ in. outside diameter and larger shall be marked with the following listed information. Marking shall be in accordance with FED-STD-183 and MIL-STD-792: (*a*) Outside diameter, wall thickness, and length (*b*) Heat or lot identification number.

33.1.10 Tube shall be straight to within the tolerances specified in Table 7.

33.1.11 When specified, each tube shall be ultrasonically examined in accordance with MIL-STD-271, except that the notch depth in the calibration standard shall be 5 % of the wall thickness or 0.005 in., whichever is greater. Any tube that produces an indication equal to or greater than 100 % of the indication from the calibration standard shall be rejected.

TABLE 7 Straightness Tolerances

Specified OD (in.)	Specified wall thickness (in.)	Maximum curvature in any 3 ft (in.)	Maximum curvature in total length (in.)
Up to 5.0, incl	Over 3 % OD to 0.5, incl	0.030	0.010 × length, ft
Over 5.0 to 8.0, incl	Over 4 % OD to 0.75, incl	0.045	0.015 × length, ft
Over 8.0 to 12.75, incl	Over 4 % OD to 1.0, incl	0.060	0.020 × length, ft

33.1.12 The tube shall be free from repair welds, welded joints, laps, laminations, seams, visible cracks, tears, grooves, slivers, pits, and other imperfections detrimental to the tube as determined by visual and ultrasonic examination, or alternate tests, as specified.

33.1.13 Tube shall be uniform in quality and condition and have a finish conforming to the best practice for standard quality tubing. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be considered injurious if the imperfections are removable within the tolerances specified for wall thickness or 0.005 in. [0.1 mm], whichever is greater. The bottom of imperfections shall be visible and the profile shall be rounded and faired-in.

33.1.14 No weld repair by the manufacturer is permitted.

33.1.15 Preservation shall be level A or commercial, and packing shall be level A, B, or commercial, as specified. Level A preservation and level A or B packing shall be in accordance with MIL-STD-163 and commercial preservation and packing shall be in accordance with Practices A 700 or Practice D 3951.

34. Keywords

34.1 alloy steel tube; austenitic stainless steel; duplex stainless steel; ferritic stainless steel; ferritic/austenitic stainless steel; heavily cold-worked steel tube; seamless steel tube; stainless steel tube; steel tube; welded steel tube

ANNEX

A1. REQUIREMENTS FOR THE INTRODUCTION OF NEW MATERIALS

A1.1 New materials may be proposed for inclusion in specifications referencing this Specification of General Requirements subject to the following conditions:

A1.1.1 Application for the addition of a new grade to a specification shall be made to the chairman of the subcommittee that has jurisdiction over that specification.

A1.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable specification.

A1.1.3 The application shall be accompanied by test data as required by the applicable specification. Test data from a minimum of three test lots, as defined by the specification, each from a different heat, shall be furnished.

A1.1.4 The application shall provide recommendations for all requirements appearing in the applicable specification.

A1.1.5 The application shall state whether the new grade is covered by patent.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 1016/A 1016M - 04, that may impact the use of this specification. (Approved July 4, 2004)

(*1*) Added 6.2.1 to provide a limitation on grade substitution for alloy steels and stainless steels.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 1016/A 1016M - 02, that may impact the use of this specification. (Approved April 4, 2004)

(*1*) Removed A 423/A 423M from Scope and Referenced Documents.

(*2*) Added heavily cold-worked tubing to Ordering Information, Flattening Test, and Keywords.

Designation: A 1015 – 01 (Reapproved 2005)

Standard Guide for Videoborescoping of Tubular Products for Sanitary Applications[1]

This standard is issued under the fixed designation A 1015; 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 standard covers guidelines for ordering and examining tubular products for sanitary applications by videoborescoping. This method uses movable camera probe at the end of a cable to examine the interior of a tubular product. The image is then transmitted to an external monitor for analysis. The method is normally used when inside surface imperfections, not normally detected by other nondestructive methods, may result in contamination of the product which is contained by the tubular product.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

3. Terminology

3.1 *Definitions*:

3.1.1 For definition of some of the terms used in this specification, refer to Specification A 941.

3.2 *Other Definitions:*

3.2.1 *collar*—a device which fits around the probe tip to control distance from the product surface and angle of viewing to ensure a consistent magnification factor.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *inclusion*—a nonmetallic particle embedded in the product surface.

3.3.2 *nick*—a surface imperfection resulting from material removal or compression usually caused by a mechanical means. It usually has a length to width ratio less than 5.

3.3.3 *oxide*—a darker, non-reflective area that is the result of improper protective gas coverage during a high temperature operation or insufficient chemical cleaning.

3.3.4 *pit*—a sharp edged surface depression usually caused by the removal of an embedded particle but may also be caused by selective metal removal by a chemical means.

3.3.5 *shrinkage*—a line of irregular shallow pores which occur along the center of a weld.

3.3.6 *scratch*—a long depression cause by a mechanical means. It usually has a length-to-width ratio greater than 5.

3.3.7 *slag pocket*—a pit, usually in a weld, caused by a particle of slag (metal oxides, carbides, fluorides or similar) which may have been cold worked into the surface. The pocket may or may not still contain slag during the examination.

3.3.8 *starburst*—a series of slag pockets where the center one is usually the largest and smaller ones radiate outward.

3.3.9 *tube*—a generic term for all tubular products including both pipe and tube.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all of the requirements that are desired under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Number of tubes to be inspected.

4.1.2 The amount of probe to tube rotation, if desired (Section 8).

4.1.3 Any special probe coverage (Section 8).

4.1.4 Special probe feed rates (Section 8).

4.1.5 Any special acceptance criteria (Section 6).

4.1.6 Supply of recording tapes and whether traceability is required (Section 9).

4.1.7 Information to be identified on recording tapes (Section 9).

4.1.8 Whether customer witnessing is required (Section 10).

4.1.9 Whether Certification is required (Section 11).

5. Significance and Use

5.1 This specification establishes some the key factors which govern the interpretation of videoborescoping tubular products for a specific application. It is recognized that the requirements for one application may be very different than those of another. Therefore, the specification allows for the inspection to be customized for the application by the user by allowing the purchaser to specify parameters which may be important for the application.

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[1] This guide 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.

Current edition approved Sept. 1, 2005. Published October 2005. Originally approved in 2001. Last previous edition approved in 2001 as A 1015 – 01.

[2] 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.

6. Acceptance Criteria

6.1 The purpose of this inspection is to identify imperfections on the ID surface of the tube which may be detrimental to the end use. These imperfections could have a variety of shapes, sizes and causes which may or may not have impact on the final use. The criteria should include a reference to the types of imperfections which are considered detrimental. These may include, but are not limited to, the following:

6.1.1 Nicks,

6.1.2 Scratches or other linear imperfections,

6.1.3 Pits,

6.1.4 Inclusions,

6.1.5 Slag pockets,

6.1.6 Starbursts,

6.1.7 Shrinkage,

6.1.8 Oxide,

6.1.9 Other weld imperfections.

6.2 Each imperfection shall be ranked by size. The criteria should include a listing of how many imperfections of a type and size are allowed per tube. It may include a listing which allows more, smaller imperfections of a type or fewer large ones. It may also include a maximum size which is allowed. The criteria may also define whether imperfections may contain deposits or not.

6.2.1 When properly calibrated, the length and width of the imperfection can be determined.

6.2.2 Imperfection depth is difficult to determine by this technique. When depth is a necessary part of the criteria, a representative sample should be agreed upon by the purchaser and supplier based upon the video image. This sample can then be sectioned and the depth measured by an alternative method.

6.3 Unless otherwise specified by the purchaser, the producer's published acceptance criteria shall be used. When no criteria exists, the acceptance criteria shall be negotiated prior to the start of testing.

7. Calibration

7.1 When imperfection sizing is part of the criteria, the videoborescope shall be calibrated prior to the examination. The following items affect sizing of imperfections for a particular unit:

7.1.1 Probe to surface distance. As the distance from the probe tip to the examined surface decreases, the magnification factor increases.

7.1.1.1 This distance shall be carefully controlled. This can be accomplished by fitting a collar to the tip of the probe which fits snugly into the inside diameter of the tube. The collar shall also have enough clearance to slide freely inside of the tube and be made of a material which will not cause additional unacceptable imperfections on the ID surface. The collar shall have sufficient length to prevent rocking of the probe which may hinder defect sizing.

7.1.2 Probe type,

7.1.3 Probe lens,

7.1.4 Display CRT. As the display screen increases, so does the magnification.

7.2 If any of the above four items, or any other factor which may affect magnification, is changed, the unit shall be recalibrated.

7.3 Calibration shall be performed using standards traceable to known National Standards, where they exist. Precision steel scales with .020" (0.5 mm) or liner graduations may be used for this calibration providing that the spacing between the probe tip and scale is controlled to be the same as probe tip and examined surface distance.

8. Method of Scanning

8.1 The method and coverage of scanning, and care shall be related to the criticality of the application (See Notes 1-3).

NOTE 1—Scanning is usually considered as a sampling technique as the inside surface coverage is often less than 100 %. As the amount of surface area per tube to be scanned increases, so does the potential for detecting an increasing number of imperfections. Therefore, as the amount of inspected surface area increases, so should the number of imperfections in the acceptance criteria for a tube of the same quality level.

NOTE 2—The videoborescoping technique is considered to be a relatively slow and expensive examination method. When deciding upon a scanning coverage and rate, the purchaser should recognize than higher coverages and slower path rates can increase the time of examination. This can have a significant impact on the overall time to perform the task and increase the cost. The purchaser should consider this when deciding upon these items.

NOTE 3—When surface finish may be critical to an application, such as those which use an electropolished finish, The user needs to choose coatings for the probe which do not damage the surface during the examination.

8.1.1 When a welded product is examined, unless otherwise specified by the purchaser, the examination shall be along the weld seam only.

8.1.2 The purchaser may specify if the examination path is linear or helical.

8.1.3 When desired, the purchaser may specify the maximum scanning rate which may be used. This is usually expressed as a tubular length per minute.

9. Recordings

9.1 When specified by the purchaser, recordings shall be made of the tube inspection. These are usually in the standard VHS format. The purchaser may specify if the recordings are to be from every tube or per a sample plan.

9.2 When traceability between tube and recording is required, the supplier shall provide a method to identify each tube to the recording. If special information is to be identified on these recordings, the purchaser shall include this in the purchase order.

9.3 If defect sizing is utilized for acceptance of the tube, the supplier shall identify the size of the video monitor used during the inspection.

10. Inspection

10.1 The inspector representing the purchaser shall have entry, at all times, to those areas where the inspection is being performed. The supplier shall afford the inspector all reasonable facilities to satisfy him that the material is being examined in accordance with this specification. The inspection shall be conducted so as not to interfere unnecessarily with the examination.

11. Certification

11.1 When required by the purchaser, the supplier shall furnish a statement that the material has been examined and has met all of the requirements of this specification and the customer purchase order.

12. Keywords

12.1 pipe; tube; tubular product; videoborescoping

Standard Specification for Precipitation-Hardening Bolting Material (UNS N07718) for High Temperature Service[1]

This standard is issued under the fixed designation A 1014/A 1014M; 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 covers a precipitation hardening bolting material (UNS N07718) for high temperature service.

1.2 This specification is expressed in both inch-pound and in SI units. However, unless the order specifies the applicable "M" designation (SI units), the material shall be furnished to inch-pound units.

1.3 The values stated in either inch-pounds 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.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range

B 637 Specification for Precipitation-Hardening Nickel Alloy Bars, Forgings, and Forging Stock for High-Temperature Service

B 880 Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys

E 112 Test Methods for Determining Average Grain Size

E 292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials

2.2 *ANSI Standards:*

B1.1 Screw Threads[3]

2.3 *SAE Standards:*

AS 7467 Bolts And Screws, Nickel Alloy, UNS N07718 Tensile Strength 185 KSI [1275 MPa] Stress Rupture Rated Procurement Specification[4]

3. Ordering Information

3.1 *Ordering*—It shall be the responsibility of the purchaser to specify all requirements that are necessary for product under this specification including any supplementary ones and those included in the ordering information required by Specification A 962/A 962M.

4. Common Requirements

4.1 *Common Requirements*—Product furnished to this specification shall conform to Specification A 962/A 962M, including any supplementary requirements indicated on the purchase order. Failure to comply with Specification A 962/A 962M constitutes non-conformance with this specification. If the requirements of this specification conflict with those of Specification A 962/A 962M, then the requirements of this specification shall prevail.

5. Manufacture

5.1 *Melting Process*—Alloy shall be multiple melted using consumable electrode practice in the remelt cycle or shall be induction melted under vacuum. If consumable electrode remelting is not performed in vacuum, electrodes produced by vacuum induction melting shall be used.

5.2 *Heat Treatment*:

5.2.1 *Solution Treatment*—Material shall be solution heat treated at a temperature within the range of 1725 to 1850 °F [940 to 1010 °C], held at the selected temperature for a time commensurate with cross-sectional thickness, and cooled at a rate equivalent to an air cool or faster.

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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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] 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.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

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

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

5.2.1.1 *Temperature Variation*—Solution treating temperatures shall be controlled in the range of ± 25 °F [± 14 °C].

5.2.2 *Precipitation Heat Treatment*—Material shall be heated to a temperature of 1325 °F [720 °C], held at temperature for eight hours minimum, furnace cooled to 1150 °F [620 °C] at 100 °F [55 °C] per hour, held at temperature for eight hours, and cooled to room temperature. Alternatively, material may be furnace cooled to 1150 °F [620 °C] at any rate provided the time at 1150 °F [620 °C] is adjusted so the total precipitation heat treatment time is 18 hours minimum.

5.2.2.1 *Temperature Variation*—Precipitation treatment temperatures and cooling rates shall be controlled in the range of ± 15 °F [± 8 °C].

5.3 *Straightening*—When straightening is necessary it shall be done after solution treating and prior to aging. Straightening after aging is prohibited.

5.4 *Threads*—Threads shall be formed by rolling in one pass after oxides have been removed from the area to be threaded.

5.5 *Dimensions and Tolerances, Bolting Material*—Fully heat treated bolting material shall meet the dimensional requirements of Specification B 637 for UNS N07718.

6. Chemical Composition

6.1 *Remelt Ingots*—The chemical analyses of each remelted ingot shall conform to the requirements for chemical composition prescribed in Table 1.

6.2 *Product Analysis*—If a product (check) analysis is performed by the purchaser, the material shall conform to the product (check) analysis variations prescribed in Specification B 880.

7. Mechanical Properties

7.1 *Tensile and Hardness*—All testing shall be performed after aging. The test specimens shall meet the requirements of Table 2.

7.2 *Stress Rupture*—Stress rupture testing shall be conducted in accordance with Table 2 using a combination test bar in accordance with Test Methods E 292. Rupture must occur in the smooth section of each test specimen.

7.3 *Headed Fasteners*—In addition to 7.1 and 7.2, headed fasteners with body length three times the diameter or longer shall be subjected to full size tensile test in accordance with Annex A3 of Test Methods and Definitions A 370 and shall conform to the tensile strength shown in Table 2. The minimum full size breaking strength (lbf) [Kn] for individual sizes shall be as follows:

$$Ts = UTS \times As \quad (1)$$

where:
Ts = tensile strength,
UTS = tensile strength specified in Table 2, and
As = stress area, square inches [square milimetres], as shown in ANSI B1.1 or calculated as follows:

$$As = 0.785\,(D - (0.974/n)\,)^2 \quad (2)$$

where:
D = nominal thread size, and
n = the number of threads per inch.

$$[As = 0.785\,(D - 0.9382P)^2] \quad (3)$$

[where:
D = Nominal thread size, and
P = Thread pitch, mm.]

TABLE 1 Chemical Requirements

Element	UNS N07718 (Formerly Grade 718)
Carbon, max.	0.08
Manganese, max.	0.35
Silicon, max.	0.35
Phosphorus, max.	0.015
Sulfur, max.	0.015
Chromium	17.0–21.0
Cobalt, max.[A]	1.0
Molybdenum	2.80–3.30
Columbium + Tantalum	4.75–5.50
Titanium	0.65–1.15
Aluminum	0.20–0.80
Boron, max.	0.006
Iron[B]	Remainder
Copper, max.	0.30
Nickel[C]	50.0–55.0

[A] If determined.
[B] Determined arithmetically by difference.
[C] Nickel + Cobalt.

TABLE 2 Mechanical Properties

Tensile and Hardness	
Tensile strength, min, ksi [Mpa]	185 [1275]
Yield Strength, min, ksi, [Mpa] 0.2 % offset	150 [1035]
Elongation in 2 in., or 50 mm (or 4D) min %	12
Reduction of area, min, %	15
Hardness, Brinell	331–444
Stress Rupture Requirements	
Temperature, °F [°C]	1200 [650]
Stress, ksi [Mpa]	100 [690]
Hours, min	23
Elongation in 2 in., or 50 mm (or 4D), min %	5
Elevated Tensile Requirements	
Temperature, °F [°C]	1200 [650]
Tensile strength, min, ksi [Mpa]	145 [1000]
Yield Strength, min, ksi, [Mpa] 0.2 % offset	125 [860]
Elongation in 2 in., or 50 mm (or 4D) min %	12
Reduction of area, min, %	15

8. Metallography

8.1 *Microstructure*—The microstructure shall be free of freckles, white spots, and Laves phases. Threads may show evidence of cold working as a result of rolling. The average grain size shall be determined in accordance with Test Methods E 112 and found to be ASTM No 5 or finer. Up to 20 % of the structure may have a grain size as large as a No. 3 due to the presence of noncrystallized grains.

8.2 *Macrostructure*—Fasteners produced from forgings shall exhibit continuous flow lines in the threads and in any shank to head or fillet and/or bearing surface areas.

9. Number of Tests

9.1 *Chemistry*—One test per remelt ingot.

9.2 *Mechanical Properties*—The number of tests shall be in accordance with Specification A 962/A 962M except that for stress rupture one test shall be run per lot. For headed fasteners with a body length less than three times the diameter a separately forged test bar may be used for tensile and stress rupture testing provided it is heat-treated with the parts. Separately forged bars shall be approximately the same diameter as the headed fastener they represent.

9.3 *Grain Size*—One test per lot.

9.4 *Flow Lines*—One test per lot on forged fasteners after final machining.

9.5 *Headed Fasteners*—One tensile test per lot.

10. Workmanship

10.1 *Bolting Material*—Shall be uniform in quality and condition, smooth, commercially straight or flat, and free of injurious imperfections.

10.2 *Fasteners*—Multiple laps on thread flanks are prohibited. Seams, laps, notches, slivers, or oxide scale in the root area of threads are prohibited. Cracks are prohibited.

11. Product Marking

11.1 *Marking*—Fasteners shall be marked with "718" and the manufacturer's identification symbol.

12. Certification

12.1 *Report*—In addition to the requirements of A 962/A 962M, certification shall include the solution treatment cycle time and temperature and the aging cycle time(s) and temperature(s).

13. Keywords

13.1 bolts; fasteners; Inconel 718; nickel alloy; precipitation hardening; temperature service application – high

SUPPLEMENTARY REQUIREMENTS

These requirements do not apply unless specified in the purchase order and in the Ordering Information, in which event the specified tests shall be made before shipment of the product.

S1. Protective Atmosphere

S1.1 Heat treatment shall be performed under suitable protective atmosphere.

S2. Cleaning

S2.1 Parts shall be cleaned with nitric acid as stated in AS 7467

S3. Fillet Rolling

S3.1 The fillet area of the fastener head shall be rolled.

S4. Forged Heads

S4.1 Heads shall be forged.

S5. Marking

S5.1 Fastener marking shall include heat lot identification.

S5. Thread Rolling

S5.1 Thread rolling shall be performed before precipitation heat treatment.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 1014 – 03, that may impact the use of this specification. (Approved March 1, 2006)

(*1*) Revised to inch-pound/SI specification.

Designation: A 1012 – 02 (Reapproved 2007)

Standard Specification for Seamless and Welded Ferritic, Austenitic and Duplex Alloy Steel Condenser and Heat Exchanger Tubes With Integral Fins[1]

This standard is issued under the fixed designation A 1012; 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 describes seamless and welded ferritic, austenitic and duplex alloy steel tubing on which the external or internal surface, or both, has been modified by a cold forming process to produce an integral enhanced surface for improved heat transfer. The tubes are used in surface condensers, evaporators, heat exchangers and similar heat transfer apparatus in unfinned end diameters up to and including 1 in. (25.4 mm). Boiler tubes are excluded.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 The following precautionary statement pertains to the test method portion only, Section 12, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 213/A 213M Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes

A 249/A 249M Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes

A 268/A 268M Specification for Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service

A 269 Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

A 688/A 688M Specification for Welded Austenitic Stainless Steel Feedwater Heater Tubes

A 789/A 789M Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service

A 803/A 803M Specification for Welded Ferritic Stainless Steel Feedwater Heater Tubes

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

3. Terminology

3.1 *Definitions*—For definition of general terms used in this specification, refer to Specification A 941.

3.2 *Symbols (Integral Fin Tube Nomenclature)*:

D = outside diameter of unenhanced section
D_i = inside diameter of unenhanced section
d_r = root diameter of enhanced section outside of tube
d_o = outside diameter of enhanced section
d_i = inside diameter of enhanced section
W = wall thickness of unenhanced section
W_f = wall thickness of enhanced section
F_h = height of fin—enhanced section outside of tube
F_m = mean fin thickness—enhanced section outside of tube
P = mean rib pitch—enhanced section inside of tube
R_h = height of rib—enhanced section inside of tube
H_a = rib helix angle—enhanced section inside of tube
T_t = transition taper

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 ASTM designation and year of issue (this specification);

4.1.2 ASTM designation and year of issue (plain tube 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 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.

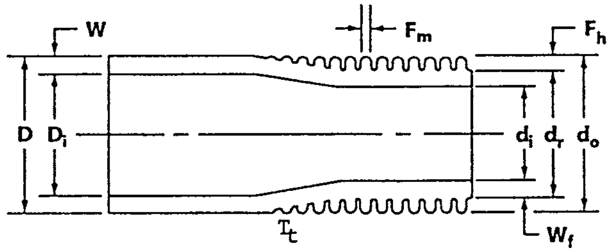

FIG. 1 Outside Enhancement Only

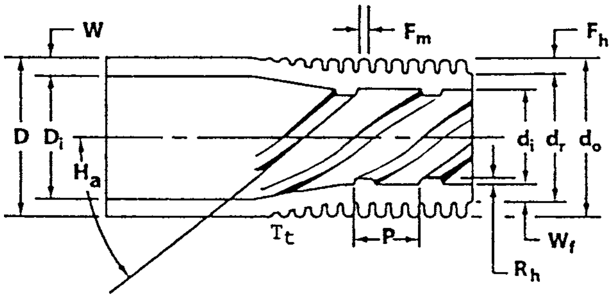

FIG. 2 Outside and Inside Enhancement

4.1.3 Welded or seamless;

4.1.4 Alloy grade and UNS designation;

4.1.5 Dimensions; plain tube outside diameter, plain tube wall thickness (average or minimum specified), length and location of unenhanced surfaces and the total tube length. Configuration of enhanced surfaces (fins per unit length, fin height, wall thickness under fin, rib pitch, rib height, etc.) shall be as agreed upon between the manufacturer and purchaser (see Figs. 1 and 2).

4.1.6 Temper (as-finned or stress relief annealed);

4.1.7 Quantity;

4.1.8 Packaging;

4.1.9 Nondestructive tests;

4.1.10 Customer inspection;

4.1.11 Mill test report;

4.1.12 Certification.

5. General Requirements

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

5.2 Enhanced (integrally finned) sections of the tube shall be produced by cold forming the tubing in such a manner that exterior fins, wall under the fin and inside ribs (when specified) are homogeneous.

5.3 Tubes described by this specification shall be furnished with unenhanced (plain) ends.

5.4 Enhanced sections of the tube are normally supplied in the "as finned" temper (cold worked condition produced by the enhancing operation). The unenhanced sections of the tube shall be in the annealed condition and shall be suitable for rolling-in operations.

6. Materials and Manufacture

6.1 The integrally enhanced (finned) tubes shall be manufactured from seamless, welded, or welded/cold worked plain tubes that conform to one of the following ASTM specifications: A 213/A 213M, A 249/A 249M, A 268/A 268M, A 269, A 688/A 688M, A 789/A 789M, A 803/A 803M.

7. Temper

7.1 The tube after enhancing shall normally be supplied in the as-finned temper. When specified by the purchaser, for bending, coiling or other fabricating operations, enhanced portions of the tube may be stress relief annealed or solution annealed.

7.2 Heat treatment of enhanced sections, or bend areas, or both, shall be in accordance with the governing plain tube specification.

8. Chemical Composition

8.1 The tubing specified shall conform to the chemical requirements prescribed in the governing plain tube specification.

9. Tensile Requirements

9.1 The tube prior to the finning operation, or unenhanced portions of the finned tube, shall conform to the requirements for tensile properties prescribed in the governing plain tube specification.

10. Permissible Variations in Dimensions

10.1 *Diameter*—The outside diameter of the unenhanced sections shall not exceed the diameter tolerances shown in the governing plain tube specification as measured by micrometers and verified by "go" and "no go" ring gages. The diameter over the enhanced sections shall not exceed the diameter of the plain sections involved, as determined by a "go" ring gage unless otherwise specified. The dimensions of the ring gages shall be as described in 10.1.1 and 10.1.2.

10.1.1 The inside diameter dimension of the "go" ring gage shall be equal to the nominal tube diameter, plus the maximum tolerance, plus .002 in. The length of the "go" ring gage shall be 1 in. (25.4 mm) minimum.

10.1.2 The inside diameter dimension of the "no go" ring gage shall be equal to the nominal tube diameter minus the maximum tolerance. The length of the "no go" ring gage shall be 1 in. (25.4 mm) minimum.

10.2 *Wall Thickness*—The wall thickness of enhanced and unenhanced sections shall not exceed the thickness tolerances shown in the governing plain tube specification unless otherwise agreed to between the manufacture and purchaser. No tube at any point shall be less than the minimum thickness specified in the plain sections or in the enhanced sections.

10.3 *Length*—The length of the tubes shall not be less than that specified, but may exceed the specified value by the amounts given in Table 1.

TABLE 1 Length Tolerances

Specified Length, ft (m)	Tolerance, in. (mm)
Up to 24 (7.3), incl	+ ⅛ (3.2)
Over 24 to 34 (7.3 to 10.4), incl	+ ¼ (6.4)
Over 34 to 44 (10.4 to 13.4), incl	+ ⅜ (9.5)
Over 44 (13.4)	+ ½ (12.7) max

10.3.1 The length of plain ends, as measured from the tube end to the first tool impression, shall not be less than that specified, but may exceed the specified value by ½ in. (12.7 mm).

10.3.2 The length of fin sections and lands (unenhanced portions) shall be as specified ± ¼ in. (6.35 mm).

10.4 *Squareness of Cut*—The angle of cut of the end of any tube may depart from square by not more than 0.016 in.

10.5 *Straightness*—The tube shall be reasonably straight and free of bends or kinks.

11. Workmanship, Finish and Appearance

11.1 Finished tubes shall be clean and free of foreign material, shall have smooth ends free of burrs, and shall be free of injurious external and internal imperfections. Minor defects may be removed, provided the dimensional tolerances of Section 10 are not exceeded.

11.2 A slight amount of oxidation on the surface resulting from heat treatment after enhancing or bending is acceptable. When the plain tube specification allows for a slight amount of oxidation on the surface resulting from heat treatment, this also is acceptable.

12. Nondestructive Tests

12.1 After enhancing operations, subject each tube to a nondestructive electromagnetic test, and either a pneumatic or hydrostatic test as specified in the purchase order. Tubes normally shall be tested in the as-fabricated condition but, at the option of the manufacturer or purchaser, may be tested in the stress relief annealed condition.

12.1.1 *Eddy Current Test*—Eddy current inspect the tube by passing it through an encircling coil designed to test the entire cross section of the tube.

12.1.1.1 The reference standard used to adjust the sensitivity setting of the apparatus shall be sound and of the same nominal alloy, enhanced configuration, condition (temper), and nominal dimensions as the lot of tubes to be tested on a production basis. Drill four holes not larger than 0.031 in. (0.787 mm) in diameter radially through the enhanced wall in each of four successive planes at 0°, 90°, 180°, and 270°. Use a suitable drill jig to guide the drill, taking care to avoid distortion of the adjacent fins. Locate one hole in the weld for welded material. Space artificial discontinuities at least 16 in. (406 mm) apart to provide signal resolution adequate for interpretation. Discard and replace the reference standard when erroneous signals are produced from mechanical, metallurgical, or other damage to the tube.

12.1.1.2 Adjust the eddy current test unit to obtain an optimum signal-to-noise ratio with the minimum sensitivity required to detect all four artificial defects in the reference standard on a repeatable basis. Equipment adjustments and tube speed maintained during calibration shall be the same for production tubes.

12.1.1.3 Set aside tubes showing an eddy current indication in excess of any signal obtained from artificial defects in the reference standard and subject them to retest or rejection.

12.1.1.4 Tubes causing irrelevant signals because of debris and like effects shall be considered to conform, should they not cause output signals beyond acceptable limits when retested. Tubes causing irrelevant signals because of visible and identifiable handling marks (rough fin tip, notches in the fin) shall be considered to conform, provided the wall thickness in the enhanced and unenhanced areas is not less than the minimum specified.

12.1.1.5 Tubes causing relevant signals because of injurious defects (incomplete welds, splits, embedded debris, broken tool impressions, ID defects), that reduce the wall thickness below the minimum specified shall be rejected. If, after retest and examination, no source for the reject signal can be discerned, the tube shall be rejected.

12.1.2 *Pneumatic Test*—When examined with this test method, each tube shall withstand a minimum internal air pressure of 250 psi (1.72 MPa), for a minimum of 5s, without showing evidence of leakage. The test method used shall permit easy detection of any leakage either by placing the tube underwater or by using the pressure differential method as follows:

12.1.2.1 *Air Underwater Pressure Test*—Each tube shall be tested in accordance with Specification A 1016/A 1016M except using test pressure specified in 12.1.2.

12.1.2.2 *Pressure Differential Test*—Procedure and acceptance criteria shall be agreed upon between the manufacturer and purchaser.

12.1.3 *Hydrostatic Test*—When examined with this test method, each tube shall be tested in accordance with Specification A 1016/A 1016M, except, the equation for calculating test pressure shall be modified as follows:

$$Inch-Pound\ Units: P = 32\,000\ W_f / d_r \tag{1}$$

$$SI\ Units: P = 220.6\ W_f / d_r$$

where:

P = hydrostatic test pressure, psi (or MPa),
W_f = wall under fin thickness, in. (or mm),
d_r = fin root diameter, in. (or mm),

12.1.3.1 As agreed upon between the manufacturer and purchaser, a minimum hydrostatic test pressure in excess of the requirements of Specification A 1016/A 1016M may be stated on the order. The tube wall stress shall be determined by the following equation:

$$S = Pd_r / 2W_f \tag{2}$$

where:

S = tube wall stress, psi (or MPa), and all other symbols as defined in 12.1.3.

12.1.3.2 The hydrostatic test may be performed before the tube is cut to final length but must be performed after enhancing, bending, heat treatment, or other forming operations.

13. Inspection

13.1 The manufacturer shall inspect and make the necessary tests to verify that the enhanced tubes furnished conform to the requirements of the customer purchase order and to the requirements of this specification.

13.2 Should the purchaser additionally elect to perform his own inspection, the manufacturer shall make provisions for such in accordance with requirements specified in Specification A 1016/A 1016M.

14. Rejection

14.1 Provisions for rejection shall be in accordance with requirements in Specification A 1016/A 1016M.

15. Certified Test Report

15.1 The manufacturer shall furnish to the purchaser a certified test report in accordance with requirements specified in A 1016/A 1016M.

15.2 In addition, the certified test report shall include the following information and test results, as modified, when applicable:

15.2.1 *Plain Tube*:

15.2.1.1 ASTM material designation.

15.2.1.2 Welded or seamless.

15.2.1.3 Alloy grade and UNS designation.

15.2.1.4 Tube dimensions (outside diameter and wall thickness).

15.2.1.5 Heat number.

15.2.1.6 Heat analysis.

15.2.1.7 Product analysis, when specified.

15.2.1.8 Tensile properties.

15.2.1.9 Flattening test acceptable.

15.2.1.10 Reverse flattening test acceptable.

15.2.1.11 Flaring test acceptable.

15.2.1.12 Flange test acceptable.

15.2.1.13 Hardness test values.

15.2.1.14 Hydrostatic or pneumatic test pressure and test results.

15.2.1.15 Non-destructive electric test method and test results.

15.2.1.16 Impact test results.

15.2.1.17 Other test results or information required to be reported by the product specification.

15.2.1.18 Test results or information required to be reported by supplementary requirements, or other requirements designated in the purchase order shall be reported, but may be reported in a separate document.

15.2.2 *Enhanced Tube*:

15.2.2.1 ASTM material designation.

15.2.2.2 Manufacturer name and order number.

15.2.2.3 Customer name and purchase order number.

15.2.2.4 Product description or part number.

15.2.2.5 Quantity.

15.2.2.6 Eddy current test results.

15.2.2.7 Pneumatic test pressure and test results, when specified.

15.2.2.8 Hydrostatic test pressure and test results, when specified.

15.2.2.9 Stress relief annealed, when specified.

15.2.2.10 Results of any other checks or testing required by the customer purchase order.

16. Packaging and Package Marking

16.1 The tube shall be packaged in accordance with the manufacturer's standard practice, unless otherwise agreed upon between the manufacturer and the purchaser and so stated in the purchase order.

16.2 Each shipping unit shall be legibly marked with the name of the supplier, name of the customer, ship to address, purchase order number, alloy designation, size or part number, tube length and number of pieces.

17. Keywords

17.1 alloy steel tube; austenitic stainless steel; carbon steel tube; condenser tube; duplex stainless steel; feedwater heater tubes; ferritic/austenitic stainless steel; ferritic stainless steel; heat exchanger tube; high temperature applications; seamless steel tube; stainless steel tube; steel tube; superheater tube; temperature service applications—high; welded steel tube

Standard Specification for
Steel Line Pipe, Black, Plain End, Laser Beam Welded[1]

This standard is issued under the fixed designation A 1006/A 1006M; 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 covers laser beam welded, black, plain end steel pipe for use in the conveyance of fluids under pressure. Pipe in sizes NPS 1 to 26, inclusive, with nominal wall thickness 0.750 in. [19.1 mm] or less, as given in Table 1, is included. Pipe having other dimensions, in this size range, may be furnished provided such pipe complies with all other requirements of this specification.

1.2 It is intended that the pipe be capable of being circumferentially welded in the field when welding procedures in accordance with the requirements of the applicable pipeline construction code are used.

1.3 The values stated in either inch-pound units or in SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values in each system are not exact equivalents: therefore, each system is to be used independently of the other, without combining values in any way.

1.4 The following precautionary statement pertains to the test method portion, Section 14, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 941 Standard Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

TABLE 1 Dimensions and Weight [Mass] Per Unit Length

NOTE—Pipe having an outside diameter and/or wall thickness intermediate to those listed in this table are also permitted.

NPS	Outside Diameter		Wall Thickness		Weight [Mass] per Unit Length	
Designator	in.	mm	in.	mm	lb/ft	kg/m
1	1.315	33.4	0.133	3.4	1.68	2.52
			0.358	9.1	3.66	4.55
1¼	1.660	42.2	0.140	3.6	2.27	3.43
			0.382	9.7	5.22	7.77
1½	1.900	48.3	0.145	3.7	2.72	4.07
			0.400	10.2	6.41	9.58
2	2.375	60.3	0.083	2.1	2.03	3.01
			0.436	11.1	9.04	13.47
2½	2.875	73.0	0.083	2.1	2.48	3.67
			0.552	14.0	13.71	20.37
3	3.500	88.9	0.083	2.1	3.03	4.50
			0.600	15.2	18.60	27.63
3½	4.000	101.6	0.083	2.1	3.48	5.15
			0.318	8.1	12.52	18.68
4	4.500	114.3	0.083	2.1	3.92	5.81
			0.674	17.1	27.57	40.99
5	5.563	141.3	0.083	2.1	4.86	7.21
			0.750	19.1	38.59	57.56
6	6.625	168.3	0.083	2.1	5.80	8.61
			0.750	19.1	47.10	70.27
8	8.625	219.1	0.125	3.2	11.36	17.04
			0.750	19.1	63.14	94.20
10	10.750	273.1	0.156	4.0	17.67	26.54
			0.750	19.1	80.18	119.64
12	12.750	323.9	0.172	4.4	23.13	34.67
			0.750	19.1	96.21	143.56
14	14.000	355.6	0.188	4.8	27.76	41.52
			0.750	19.1	106.23	158.49
16	16.000	406.7	0.188	4.8	31.78	47.54
			0.750	19.1	122.27	182.42
18	18.000	457	0.188	4.8	35.80	53.53
			0.750	19.1	138.30	206.25
20	20.000	508	0.219	5.6	46.31	69.38
			0.750	19.1	154.34	230.27
22	22.000	559	0.219	5.6	50.99	76.42
			0.750	19.1	170.37	254.30
24	24.000	610	0.250	6.4	63.47	95.26
			0.750	19.1	186.41	278.32
26	26.000	660	0.250	6.4	68.82	103.15
			0.750	19.1	202.44	301.87

[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 A01.09 on Carbon Steel Tubular Products.

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[2] 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.

2.2 *API Publication:*

API RP 5L3 Recommended Practice for Conducting Drop-Weight Tear Tests on Line Pipe[3]

2.3 *ASME Standard:*

ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *laser beam welding, n*—a welding process that utilizes a laser beam to produce melting of full thickness of edges to be welded, followed by the fusion of those edges.

3.1.2 *specified outside diameter*, *n*—the outside diameter shown in the purchase order or in Table 1 for the applicable NPS size.

3.2 *Definitions*—For definitions of other terms used in this specification, refer to Terminology A 941.

TABLE 2 Tensile Requirements

Grade	Yield Strength,[A] min.		Yield Strength,[A] max.		Tensile Strength, min.	
	psi	MPa	psi	MPa	psi	MPa
35	35 000	240	65 000	450	60 000	415
50	50 000	345	77 000	530	70 000	485
60	60 000	415	80 000	550	75 000	515
70	70 000	485	87 000	600	80 000	550
80	80 000	550	97 000	670	90 000	620

[A] Yield strength requirements are not applicable for transverse weld tests.

4. Ordering Information

4.1 Information items to be considered, if appropriate, for inclusion in the purchase order are as follows:

4.1.1 Specification designation and year of issue,

4.1.2 Quantity (feet or metres),

4.1.3 Grades (see Table 2 or 8.6),

4.1.4 Size, either nominal (NPS) or outside diameter and wall thickness,

4.1.5 Nominal length (see 16.3),

4.1.6 End finish (plain end beveled or special, see 17.1),

4.1.7 Bar coding (see 20.3),

4.1.8 Special requirements, and

4.1.9 Supplementary requirements.

5. General Requirements

5.1 Pipe furnished under this specification shall conform to the applicable requirements of Specification A 530/A 530M unless otherwise provided herein.

6. Materials and Manufacture

6.1 Pipe shall be welded from one side by the laser beam welding process using a single pass with an appropriate shielding gas. The pipe shall have one longitudinal seam. The weld shall be made in accordance with a qualified welding procedure as specified in ASME Boiler and Pressure Vessel Code, Section IX, Paragraph QW-264. The edges may be preheated.

6.2 The internal and external weld protrusion resulting from the welding process shall be removed, in accordance with the requirements of 18.1 and 18.2.

6.3 The weld seam and its heat affected zone shall receive either a normalizing heat treatment or a continuous in-line heat treatment in such a manner that no untempered martensite remains. Complete penetration and coverage of the weld and the weld heat affected zone by this heat treatment shall be confirmed by periodic metallographic examination of weld area cross-section specimens at least once per working shift.

7. Chemical Composition

7.1 The steel shall contain no more than 0.22 % carbon, 0.015 % sulfur, and 0.025 % phosphorus, by heat and product analyses.

7.2 The steel shall contain no more than 0.0007 % boron, by heat analysis.

7.3 The carbon equivalent (CE) value for each heat shall not exceed 0.40 %, calculated using the product analyses and the following equation:

$$CE = C + F\left[\frac{Mn}{6} + \frac{Si}{24} + \frac{Cu}{15} + \frac{Ni}{20} + \frac{Cr + Mo + V + Cb}{5}\right] \quad (1)$$

where:

F = a compliance factor that is dependent upon the carbon content, as shown below:

Carbon Content, %	F	Carbon Content, %	F
<0.06	0.53	0.14	0.85
0.06	0.54	0.15	0.88
0.07	0.56	0.16	0.92
0.08	0.58	0.17	0.94
0.09	0.62	0.18	0.96
0.10	0.66	0.19	0.97
0.11	0.70	0.20	0.98
0.12	0.75	0.21	0.99
0.13	0.80	0.22	1.00

7.4 A heat analysis shall be made for each heat of steel furnished under this specification.

7.5 Product analyses shall be made on at least two samples from each heat of steel.

7.6 All analyses shall be in accordance with Test Methods, Practices, and Terminology A 751, and shall include all elements required in the carbon equivalent equation of 7.3, in addition to titanium, phosphorus, sulfur, and boron, except that the product analysis for boron is not required. Titanium is reported for information only and is not a cause for rejection.

7.7 If one or both of the product analyses representing a heat fails to conform to the specified requirements, the heat shall be rejected, or two additional analyses shall be made on the sample that failed, each of which shall conform to the specified requirements.

8. Tensile Property Requirements

8.1 The material shall conform to the requirements for tensile properties given in Table 2 and in 8.6. The yield strength maxima apply only to pipe NPS 8 and larger.

8.2 The yield strength corresponding to a total extension under load of 0.5 % of the gage length shall be determined.

[3] Available from American Petroleum Institute (API), 1220 L Street, N.W., Washington, DC 20005-4070.

[4] Available from ASME International, Three Park Avenue, New York, NY 10016-5990.

8.3 A test specimen taken across the weld shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe required. Test specimens shall exhibit at least 10 % elongation in 2 in. [50 mm]. This test is not required for pipe under NPS 8.

8.4 Transverse tension tests shall be performed on NPS 8 and larger and the specimens shall be taken opposite the weld. All transverse test specimens shall be approximately 1½ in. [38 mm] wide in the gage length and shall represent the full wall thickness of the pipe from which the specimen was cut.

8.5 For pipe smaller than NPS 8, longitudinal tests shall be performed. Such tests shall be either strip specimens taken approximately 90° from the weld or full section specimens, at the option of the manufacturer.

8.6 Grades intermediate to those shown in Table 2 may be furnished. For such grades, the permissible yield strength range shall be as given in Table 2 for the next higher grade, and the required minimum tensile strength shall exceed the required minimum yield strength by the same amount as is given in Table 2 for the next higher grade.

8.7 The minimum elongation in 2 in. [50 mm] for all grades shall be determined by the following equation:

$$e = C\frac{A^{0.2}}{U^{0.9}} \tag{2}$$

where:

e = minimum elongation in 2 in. [50 mm], percent, rounded to the nearest percent,
C = 625 000 [1940],
A = the lesser of 0.75 in^2 [485 mm^2] and the cross-sectional area of the tensile test specimen, based on the specified outside diameter or the nominal specimen width and the specified wall thickness, rounded to the nearest 0.01 in^2 [1 mm^2], and
U = specified minimum tensile strength, psi [MPa].

9. Charpy V-Notch Test

9.1 Pipe body test specimens shall be taken approximately 90° from the weld.

9.2 The Charpy test specimens used shall be those given in Table 3, except that it shall be permissible to use ⅔ or ½ size test specimens as required when the absorbed energy is expected to exceed 80 % of the full scale capacity of the testing machine.

9.3 The minimum average absorbed energy of pipe body for any Charpy V-notch test shall be calculated from the equation given below for pipe NPS 5 through NPS 26. Values calculated by this equation as less than 30 ft-lbf [40 J] shall be taken as 30 ft-lbf [40 J] minimum average.

$$CV\,(\text{fullsize}) = C \times \sqrt{D} \times S^{1.5} \tag{3}$$

where:

CV = minimum average value required, ft-lbf [J],
C = 0.024 [0.000 354],
D = specified outside diameter, in. [mm], and
S = 0.72 × specified minimum yield strength, ksi [MPa].

NOTE 1—Charpy testing is not required on any pipe smaller than NPS 5 or for pipe NPS 5 or larger with insufficient specified wall thickness to permit at least ½ size specimens to be obtained.

9.4 When subsize specimens are used, the minimum average absorbed energy shall be that specified for full size specimens multiplied by 0.67 (for ⅔ size specimens) or 0.50 (for ½ size specimens), rounded to the nearest whole number.

9.5 Testing shall be conducted at a test temperature of 32°F [0°C], or lower.

9.6 For pipe body tests, each Charpy specimen shall exhibit at least 75 % shear area.

10. Weld Ductility Test

10.1 *Flattening Test*—The flattening test shall be conducted by tests on full section specimens of 2 in. [50 mm] minimum length. The specimens shall be flattened cold between parallel plates. The weld shall be placed at 90° and at 0° from the direction of applied force. No crack or breaks exceeding ⅛ in. [3 mm] in any direction in the weld or in the parent metal shall occur on the outside surface until the distance between the plates is less than the value of H in the following equation,

TABLE 3 Relationship Between Pipe Dimensions and Required Charpy Specimens

NOTE—Charpy testing is not required on any pipe smaller than NPS 5 or for pipe NPS 5 or larger with insufficient specified wall thickness to permit at least ½ size specimens to be obtained.

Specified OD in. [mm]	Specified Wall Thickness, in. [mm]				
	Full Size Transverse	⅔ Size Transverse	½ Size Transverse	⅔ Size Longitudinal	½ Size Longitudinal
5⁹⁄₁₆ [141.3]	0.469 and thicker [11.9 and thicker]	0.371 to 0.468 [9.4 to 11.8]	0.338 to 0.370 [8.8 to 9.3]	0.310 to 0.337 [7.9 to 9.2]	0.245 to 0.309 [6.2 to 7.8]
6⅝ [168.3]	0.460 and thicker [11.7 and thicker]	0.334 to 0.459 [8.5 to 11.6]	0.301 to 0.333 [7.6 to 8.4]	. . .	0.244 to 0.300 [6.2 to 7.5]
8⅝ [219.1]	0.450 and thicker [11.4 and thicker]	0.318 to 0.449 [8.1 to 11.3]	0.267 to 0.317 [6.5 to 8.0]	. . .	0.242 to 0.256 [6.1 to 6.4]
10¾ [273.1]	0.443 and thicker [11.3 and thicker]	0.311 to 0.442 [7.9 to 11.2]	0.246 to 0.310 [6.2 to 7.8]	. . .	0.241 to 0.245 [6.1]
12¾ [323.9]	0.438 and thicker [11.1 and thicker]	0.307 to 0.437 [7.8 to 11.0]	0.241 to 0.306 [6.1 to 7.7]	. . .	. . .
14 [355.6]	0.436 and thicker [11.1 and thicker]	0.305 to 0.435 [7.7 to 11.0]	0.238 to 0.304 [6.1 to 7.6]	. . .	. . .
≥16 [≥406.4]	0.434 and thicker [11.0 and thicker]	0.304 to 0.433 [7.7 to 10.9]	0.237 to 0.303 [6.0 to 7.6]	. . .	. . .

except that cracks that occur at the edges of the specimen and are less than ¼ in. [6 mm] long shall not be cause for rejection:

$$H = \frac{3.05\, t}{(0.05 + 3\, t/D)} \quad (4)$$

where:
H = distance between flattening plates, in. [mm],
t = specified wall thickness, in. [mm], and
D = specified outside diameter, in [mm].

10.2 *Guided Bend Test*—Root and face guided bend tests shall be conducted in accordance with Test Methods and Definitions A 370. The specimens shall not fracture completely and shall not reveal any cracks or ruptures in the fusion line longer than ⅛ in. [3 mm], except that cracks that occur at the edges of the specimen and are less than ¼ in. [6 mm] long shall not be cause for rejection.

11. Hydrostatic Test

11.1 Each length of pipe shall be subjected to the hydrostatic test without leakage through the wall.

11.2 Except as allowed by 11.5, each length of pipe NPS 2 or larger shall be tested, by the manufacturer, to a minimum hydrostatic pressure determined using the following relationship:

inch pound units:

$$P = 2\frac{St}{D} \times C \quad (5)$$

SI units:

$$P = 2000\frac{St}{D} \times C \quad (6)$$

where:
P = minimum hydrostatic test pressure, psi [kPa],
S = specified minimum yield strength, psi [MPa],
t = specified wall thickness, in. [mm],
D = specified outside diameter, in. [mm],
C = 0.60 for pipe NPS 2 through NPS 5,
= 0.75 for pipe larger than NPS 5 through NPS 8,
= 0.85 for pipe larger than NPS 8 through NPS 18, and
= 0.90 for pipe larger than NPS 18.

11.3 For pipe sizes smaller than NPS 2, the test pressures given in Table 4 are arbitrary. For intermediate diameters smaller than NPS 2, the test pressures given for the next smaller diameter shall be used.

11.4 When computed test pressures are not an exact multiple of 10 psi [100 kPa], they shall be rounded to the nearest 10 psi [100 kPa].

11.5 The minimum hydrostatic test pressure required to satisfy these requirements need not exceed 3000 psi [20 700 kPa]; however this does not prohibit testing at a higher pressure at the manufacturer's option. The hydrostatic test pressure shall be maintained for not less than 5 s for all sizes.

TABLE 4 Hydrostatic Test Pressure

NPS Designer	Specified Outside Diameter in. [mm]	Specified Wall Thickness in. [mm]	Test Pressure, Minimum psi [kPa]
1	1.315 [33.4]	0.133 [3.4]	700 [4800]
		0.179 [4.6]	850 [5900]
		0.250 [6.4]	950 [6600]
		03.58 [9.1]	1000 [6900]
1¼	1.660 [42.2]	0.140 [3.6]	1300 [9000]
		0.191 [4.9]	1900 [13 100]
		0.250 [6.4]	2000 [13 800]
		0.382 [9.7]	2300 [15 900]
1½	1.900 [48.3]	0.145 [3.7]	1300 [9000]
		0.200 [5.1]	1900 [13 100]
		0.281 [7.1]	2000 [13 800]
		0.400 [10.2]	2300 [15 900]

12. Nondestructive Examination

12.1 *General*—The weld seam of each length of pipe shall be subjected to ultrasonic inspection in accordance with 12.2.

12.2 *Ultrasonic Inspection*:

12.2.1 Any equipment utilizing the ultrasonic principles and capable of continuous and uninterrupted inspection of the weld seam shall be used. The equipment shall be checked with an applicable reference standard as described in 12.2.2 at least once every working turn with no more than 8 h between such checks to demonstrate the effectiveness of the inspection procedures. The equipment shall be adjusted to produce well-defined indications when the reference standard is scanned by the inspection unit in a manner simulating the inspection of the product. The location of the equipment for final inspection shall be after hydrostatic test.

12.2.2 *Reference Standards*—Reference standards shall have the same diameter and thickness as the product being inspected, and may be of any convenient length as determined by the pipe manufacturer. Reference standards shall be either full sections or coupons taken from the pipe. Reference standards shall contain one machined notch on the inside surface and one machined notch on the outside surface or a drilled hole, with the following dimensions:

Parallel Sided Notch	Drilled Hole
Depth: 5 %t ± 15 % with min. depth of 0.012 ± 0.002 in. [0.3 ± 0.05 mm]	¹⁄₁₆ in. [1.6 mm] dia.
Width: 0.04 in. [1 mm] max.	
Length: 2 in. [50 mm] min. at full depth	

NOTE 2—The reference standards defined in 12.2.2 contain simulated flaws for calibration of nondestructive testing equipment. The dimensions of these flaws should not be construed as the minimum size imperfection detectable by such equipment.

12.2.3 Surface condition, operator qualification, extent of examination, and standardization procedure shall be in accordance with the provisions of Specification A 450/A 450M.

12.2.4 *Acceptance Limits*—Table 5 gives the height of acceptance limit signals in percent of the height of signals produced by the reference flaws. Imperfections in the weld seam that produce a signal greater than the acceptance limit given in Table 5 shall be considered defects.

TABLE 5 Acceptance Limits

Type of Notch	Acceptance Limit Signal %
Parallel Sided Notch	100
Drilled Hole	100

12.3 *Disposition of Pipe Containing Defects*—Pipe containing defects shall be given one or more of the following dispositions:

12.3.1 The pipe length shall be rejected.

12.3.2 The portion of the pipe containing the defect shall be cut off.

12.3.3 The defect shall be removed by grinding, provided that the remaining wall thickness is within specified limits.

12.3.4 The defect shall be repaired by welding.

13. Number of Tests

13.1 Tensile testing of the pipe body and weld shall be at a frequency of one test per lot. Each lot, as given in Table 6, shall consist of each combination of specified outside diameter, specified wall thickness, and heat.

13.2 A flattening test as described in 10.1 shall be conducted on test specimens from each end of each coil length for each pipe size NPS 2 and larger. In the event of a weld stop, the test shall be performed on each pipe end adjacent to the weld stop.

13.3 For pipe NPS 10 and larger, a guided bend test shall also be performed in accordance with 10.2, at a frequency of one test per lot of 50 lengths or less of each combination of specified outside diameter, specified wall thickness, and grade.

13.4 Charpy V-notch testing of the pipe body shall be as given in Table 6 for each combination of specified outside diameter, specified wall thickness, and heat.

14. Test Methods

14.1 The mechanical properties testing required by this specification shall conform to those described in Test Methods and Definitions A 370.

15. Dimensions And Weight [Mass] Per Unit Length

15.1 The dimensions and weight [mass] per unit length shall be as given in Table 1. The weight [mass] per unit length of pipe having an intermediate outside diameter and/or wall thickness shall be determined using the following equation:

inch-pound units:

$$W = 10.69(D - t)t \tag{7}$$

SI units:

$$W = 0.02466(D - t)t \tag{8}$$

where:

W = weight [mass] per unit length, lb/ft [kg/m]
D = specified outside diameter, in. [mm], and
t = specified wall thickness, in. [mm].

16. Permissible Variation in Weight [Mass] and Dimensions

16.1 *Weight [Mass]*—The weight [mass] of a single length of pipe shall not vary more than +10 %, -3.5 % from its theoretical weight [mass]. The weight [mass] of any order item shall not be more than 1.75 % under its theoretical weight [mass].

16.2 *Wall Thickness*—The minimum wall thickness at any point shall not be more than 8 % under the specified wall thickness.

16.3 *Length*—Unless otherwise agreed upon between the purchaser and the manufacturer, pipe shall be furnished in the nominal lengths and within the permissible variation in Table 7, as specified.

16.4 *Diameter*—Pipe sizes NPS 20 and smaller shall permit the passage over the ends, for a distance of 4 in. [100 mm], of a ring gage that has a bore diameter no larger than the specified outside diameter plus the diameter plus tolerance. Diameter measurements of pipe larger than NPS 20 shall be made with a diameter tape. Diameter measurements (away from the ends) of pipe NPS 20 and smaller shall be made with a snap gage, caliper, or other device that measures actual diameter in a single plane.

17. End Finish

17.1 Pipe furnished to this specification shall be plain-end beveled with ends beveled to an angle of 30°, +5°, −0°, measured from a line drawn perpendicular to the axis of the pipe, and with a root face of 1⁄16 in. [1.6 mm] ± 1⁄32 in. [0.8 mm], or with the special plain-end configurations specified in the purchase order.

18. Workmanship, Finish and Appearance

18.1 The depth of groove resulting from the removal of the internal weld protrusion shall not be greater than that given in Table 8 for the applicable wall thickness. Depth of groove is defined as the difference between the wall thickness measured approximately 1 in. [25 mm] from the weld line and the remaining wall under the groove.

18.2 The external weld protrusion shall not extend above the surface of the pipe by more than 0.010 in. [0.25 mm].

18.3 Surface imperfections that penetrate more than 8 % of the specified wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with surface defects shall be given one of the following dispositions:

18.3.1 The defect shall be removed by grinding, provided that a smooth curved surface remains and the remaining wall thickness is within specified limits.

18.3.2 The section of the pipe containing the defect shall be cut off within the requirements for length.

18.3.3 The length shall be rejected.

18.4 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive

TABLE 6 Lot Size and Sample Size For Mechanical Testing

Size Designation	Lot Size	Sample Size
< NPS 2	50 tons or fraction thereof	1
NPS 2 through NPS 5	400 lengths	1
NPS 6 through NPS 12	200 lengths	1
> NPS 12	100 lengths	1

TABLE 7 Permissible Variations on Lengths

Nominal Length		Minimum Length		Minimum Avg. Length For Each Order Item		Maximum Length	
ft	m	ft	m	ft	m	ft	m
20	6	9.0	2.74	17.5	5.33	22.5	6.86
40	12	14.0	4.27	35.0	10.67	45.0	13.72
50	13	17.5	5.33	43.8	13.35	55.0	16.76
60	18	21.0	6.40	52.5	16.0	65.0	19.81
80	24	28.0	8.53	70.0	21.34	85.0	25.91

TABLE 8 Depth of Groove Tolerance

Specified Wall Thickness (t), in. [mm]	Maximum Depth of Groove, in. [mm]
0.150 [3.8] or less	0.10t
>0.150 [3.8] to < 0.300 [7.5]	0.015 [0.4]
0.300 [7.5] or greater	0.05t

testing device of appropriate accuracy. In case of a dispute, the measurement determined by the use of a mechanical caliper shall govern.

18.5 Repairs of the pipe body, by welding, are not permitted.

18.6 *Repair of the Weld*—Defects in welds may be repaired only by agreement between the purchaser and the manufacturer; such repairs shall be in accordance with Specification A 530/A 530M, except that the repair depth shall not exceed 70 % of the specified wall thickness of the pipe and back-to-back repairs are not permitted. No repair of repair weld is permitted.

18.7 Pipe smaller than NPS 4 shall be reasonably straight. For all other pipe, the measured deviation from a straight line shall not exceed 0.2 % of the length.

18.8 The pipe shall contain no dents greater than 10 % of the specified outside diameter or ¼ in. [6.4 mm], whichever is smaller, measured as the gap between the lowest point of the dent and a prolongation of the original contour of the pipe. Cold formed dents deeper than ⅛ in. [3.2 mm] shall be free of sharp-bottom gouges. The gouges may be removed by grinding, provided that the remaining wall thickness is within specified limits. The length of the dent in any direction shall not exceed one half the pipe diameter.

19. Certification

19.1 A certified test report shall be furnished.

20. Package Marking

20.1 Each length of pipe shall be legibly marked by stenciling to show: specification number, the name or brand of the manufacturer, LBW, the grade, wall thickness, diameter, heat number, and the length, except as allowed in 20.2. The length shall be marked in feet and tenths of a foot, or metres to two decimal places, as applicable.

20.2 For pipe NPS 1½ and smaller that is bundled, the information in 20.1 may be marked on a tag that is securely fastened to each bundle.

20.3 In addition to the requirements of 20.1 and 20.2, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used.

21. Keywords

21.1 black steel pipe; laser beam welded; line pipe

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified in the purchase order.

S1. Drop-Weight Tear Testing

S1.1 The drop-weight tear test shall be conducted in accordance with API RP 5L3.

S1.2 The temperature selected for conducting the drop-weight tear test, the test frequency, and the criteria for acceptance shall be as specified in the purchase order.

Designation: A 1005/A 1005M – 00 (Reapproved 2004)

Standard Specification for Steel Line Pipe, Black, Plain End, Longitudinal and Helical Seam, Double Submerged-Arc Welded[1]

This standard is issued under the fixed designation A 1005/A 1005M; 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 covers double submerged-arc welded, black, plain end steel pipe for use in the conveyance of fluids under pressure. Pipe in sizes NPS 16 and larger, as given in ASME B36.10, are included; pipe having other dimensions, in this size range, are permitted, provided such pipe complies with all other requirements of this specification.

1.2 It is intended that pipe be capable of being welded in the field when welding procedures in accordance with the requirements of the applicable pipeline construction code are used.

1.3 The values stated in either inch-pound units or in SI units are to be regarded separately as standard. The values in each system are not exact equivalents, therefore, each system is to be used independently of the other, without combining values in any way.

1.4 The following precautionary statement pertains to the test method portion, Section 14 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

2.2 *ASME Standards:*

ASME B36.10 Welded and Seamless Wrought Steel Pipe[3]

ASME Boiler and Pressure Vessel Code, Section VIII, Unfired Pressure Vessels[3]

ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications[3]

2.3 *API Publications:*

API RP 5L3 Recommended Practice for Conducting Drop-Weight Tear Tests on Line Pipe[4]

API Standard 1104 Welding of Pipelines and Related Facilities[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *double submerged-arc welding*, *n*—a welding process that produces coalescence of metals by heating them with an arc of arcs between a bare metal electrode or electrodes and the work pieces, using at least one pass from the inside and at least one pass from the outside to make the longitudinal, helical, and skelp end weld seams, whichever are applicable, the arc or arcs and the molten metal are shielded by a blanket of granular, fusible material on the work pieces.

3.1.2 *jointer*, *n*—not more than three lengths of pipe circumferentially welded together to produce a single length that complies with the length provisions of this specification.

3.1.3 *skelp*, *n*—the flat rolled product intended to be formed into pipe.

3.1.4 *skelp end*, *n*—the weld joining the ends of two lengths of skelp.

3.1.5 *specified outside diameter*, *n*—the outside diameter shown in B36.10M or that stated on the order.

3.1.6 *test lot*, *n*—a quantity of pipe of the same ordered diameter, heat, and wall thickness.

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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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Sept 1, 2004. Published October 2004. Originally approved in 2000. Last previous edition approved in 2000 as A 1005/A 1005M – 00$^{\epsilon 1}$.

[2] 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.

[3] Available from American Society of Mechanical Engineers (ASME), Three Park Avenue, New York, NY 10016-5990.

[4] Available from American Petroleum Institute (API), 1220 L Street, N.W., Washington, DC 20005-4070.

3.2 *Definitions:* For definitions of other terms used in this specification, refer to Terminology A 941.

4. General Requirements

4.1 Pipe furnished under this specification shall conform to the applicable requirements of Specification A 530/A 530M unless otherwise provided herein.

5. Ordering Information

5.1 Information items to be considered, if appropriate, for inclusion in the purchase order are as follows:

5.1.1 Specification designation and year of issue,

5.1.2 Quantity (feet or metres),

5.1.3 Grade (see Table 1 or 8.5),

5.1.4 Size, either nominal (NPS) or outside diameter and wall thickness,

5.1.5 Nominal length (see 16.3),

5.1.6 Diameter tolerances for pipe larger than NPS 43 (see 16.4),

5.1.7 End finish (plain and beveled or special, see 17.1),

5.1.8 Jointers (See Section 19),

5.1.9 Special requirements,

5.1.10 Supplementary requirements,

5.1.11 Charpy V-notch impact energy (see 9.4), and

5.1.12 Bar coding (see 21.2).

6. Materials and Manufacture

6.1 Skelp widths for helical seam pipe shall be neither less than 0.8 nor more than 3.0 times the pipe's specified outside diameter.

6.2 The longitudinal, helical, and skelp end welds, whichever are applicable, shall be made using welding procedures qualified in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section IX.

6.3 Skelp end welds shall not be permitted in finished pipe, except for helical seam pipe having its skelp end welds manufactured by double submerged-arc welding. For such pipe, skelp ends shall have been properly prepared for welding. Junctions of skelp end welds and helical seam welds shall not be located within 12 in. [300 mm] of pipe ends or jointer welds. Junctions of skelp end welds and jointer welds shall be separated by a minimum circumferential distance of 6 in. [150 mm] from junctions of the helical seam weld and the jointer weld. Skelp end welds shall be permitted at finished pipe ends, provided that there is a minimum circumferential separation of 6 in. [150 mm] between the skelp end weld and the helical seam weld at the applicable pipe ends.

TABLE 1 Tensile Requirements[A]

Grade	Yield Strength, min psi	Yield Strength, min MPa	Yield Strength, max psi	Yield Strength, max MPa	Tensile Strength, min psi	Tensile Strength, min MPa
35	35000	[240]	65 000	[450]	60 000	[415]
50	50000	[345]	77 000	[530]	70 000	[485]
60	60000	[415]	80 000	[550]	75 000	[515]
70	70000	[485]	87 000	[600]	80 000	[550]
80	80000	[550]	97 000	[670]	90 000	[620]

[A] Yield strength requirements do not apply to transverse weld tests.

7. Chemical Composition

7.1 The steel for any grade shall contain no more than 0.16 % carbon, by heat and product analyses.

7.2 The steel shall contain no more than 0.0007 % boron, by heat analysis.

7.3 The carbon equivalent (CE) shall not exceed 0.40 %, calculated from any reported product analysis using the following equation:

$$CE = C + F\left[\frac{Mn}{6} + \frac{Si}{24} + \frac{Cu}{15} + \frac{Ni}{20} + \frac{Cr + Mo + V + Cb}{5}\right] \quad (1)$$

where: F is a compliance factor that is dependent on the carbon content as follows:

Carbon Content, %	F	Carbon Content, %	F
<0.06	0.53	0.11	0.70
0.06	0.54	0.12	0.75
0.07	0.56	0.13	0.80
0.08	0.58	0.14	0.85
0.09	0.62	0.15	0.88
0.10	0.66	0.16	0.92

7.4 A heat analysis shall be made for each heat of steel furnished under this specification.

7.5 Product analyses shall be made on at least two samples from each heat of steel. Product analysis for boron is not required.

7.6 Except as provided in 7.5, all analyses shall be in accordance with Test Methods, Practices, and Terminology A 751, and shall include all elements required in the carbon equivalent equation of 7.3, in addition to titanium, phosphorus, sulfur, and boron.

7.7 If one or both of the product analyses representing a heat fails to conform to the specified requirements, the heat shall be rejected, or analyses shall be made on double the original number of test samples that failed, each of which shall conform to the requirements.

8. Tensile Property Requirements

8.1 Except as allowed by 8.5 the material shall conform to the requirements for tensile properties given in Table 1.

8.2 The yield strength corresponding to a total extension under load of 0.5 % of the gage length shall be determined.

8.3 A test specimen taken across the longitudinal, helical, or skelp end weld, whichever are applicable, shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe required. Test specimens shall contain the weld reinforcement and shall exhibit at least 10 % elongation in 2 in. [50 mm].

8.4 Transverse body tension test specimens shall be taken opposite the weld, for longitudinally welded pipe. For helical welded pipe the transverse body tension test shall be taken 90° to the axis of the pipe and approximately halfway between adjacent weld convolutions.

8.5 Grades intermediate to those given in Table 1 shall be furnished if so specified in the purchase order. For such grades, the permissible yield strength range shall be as given in Table 1 for the next higher grade, and the required minimum tensile strength shall exceed the required minimum yield strength by the same amount as given in Table 1 for the next higher grade.

8.6 The ratio of yield strength to tensile strength for all pipe body tests shall not exceed 0.90 for Grades 70 and lower. For grades higher than Grade 70, the ratio shall not exceed 0.93.

8.7 For pipe body tests, the minimum elongation in 2 in. [50 mm] for all grades shall be that determined by the following equation:

$$e = C\frac{A^{0.2}}{U^{0.9}} \quad (2)$$

where:

e = minimum elongation in 2 in. [50 mm] in percent, rounded to the nearest percent,
C = 625 000 [1940],
A = the lesser of 0.75 in^2 [485 mm^2] and the cross-sectional area of the tension test specimen, calculated using the specified width of the test specimen and the specified wall thickness of the pipe, with the calculated value rounded to the nearest 0.01 in^2 [1 mm^2], and
U = specified minimum tensile strength, psi [MPa].

9. Charpy V-Notch Test

9.1 Except as allowed by 9.2, all pipe shall be Charpy V-notch tested in accordance with Test Methods and Definitions A 370. All pipe body tests shall be transverse to the pipe axis, taken approximately 90° from the weld. All weld tests shall be transverse to the weld axis.

9.2 The basic specimen is full size Charpy V-notch. For pipe with a specified wall thickness of 0.236 in [5.9 mm] or less, there is no requirement for Charpy V-notch testing. Where combinations of diameter and wall do not permit the smallest specimen size, there is no requirement for proven fracture toughness. In all cases, the largest possible specimen size shall be used, except where such a specimen size will result in energy values greater than 80 % of the testing machine capacity:

Specified Wall Thickness, in. [mm]	Specimen Size To Be Used
≥0.434 [11.0]	Full
0.304–0.433 [7.7–10.9]	⅔
0.237–0.303 [6.0–7.6]	½

9.3 When specimens smaller than full size are used, the requirements of 9.4 shall be adjusted by one of the following relationships:

$$\text{For } 2/3 \text{ size: } N = R \times 0.67 \quad (3)$$
$$\text{For } 1/2 \text{ size: } N = R \times 0.50$$

where:

N = adjusted value, rounded to the nearest whole number, and
R = applicable value from 9.4 and 9.6.

9.4 The Charpy V-notch energy impact energy for the pipe body shall be not less than 30 ft-lbf [40 J] minimum average, or any higher value specified in the purchase order.

9.5 All Charpy V-notch testing shall be performed at 32°F [0°C], or lower as agreed upon between purchaser and manufacturer or at the manufacturer's option.

9.6 A test of weld and HAZ Charpy V-notch impact energy properties shall be made on each type (longitudinal, helical, or skelp end) of weld. The Charpy V-notch impact energy shall be not less than 30 ft-lbf [40 J].

9.7 Each pipe body Charpy V-notch specimen shall exhibit at least 75 % shear area.

10. Guided Bend Test

10.1 Root and face guided bend tests shall be conducted in accordance with Test Methods A 370. The specimens shall not fracture completely and shall not reveal any cracks or ruptures in the parent metal, heat affected zone, or fusion line longer than ⅛ in. [3 mm] and deeper than 12.5 % of the specified wall thickness, except that cracks that occur at the edges of the specimen and are less than ¼ in. [6 mm] long shall not be cause for rejection, regardless of depth.

11. Hydrostatic Test

11.1 Each length of pipe shall be subjected to the hydrostatic test without leakage through the wall, except that jointers that are comprised of segments that have passed hydrostatic testing need not be hydrostatically tested.

11.2 Each length of pipe shall be tested, by the manufacturer, to a minimum hydrostatic pressure calculated from the following relationship:

Inch-Pound Units:

$$P = 2\frac{St}{D} \times C \quad (4)$$

SI Units:

$$P = 2000\frac{St}{D} \times C \quad (5)$$

where:

P = minimum hydrostatic test pressure, psi [kPa],
S = specified minimum yield strength, psi [MPa],
t = specified wall thickness, in. [mm],
D = specified outside diameter, in., [mm],
C = 0.85 for pipe NPS 16 through NPS 18, and
= 0.90 for pipe larger than NPS 18.

11.3 When computed test pressures are not an exact multiple of 10 psi [100 kPa], they shall be rounded to the nearest 10 psi [100 kPa].

11.4 The minimum hydrostatic test pressure required to satisfy these requirements need not exceed 3000 psi [20 700 kPa]. This does not prohibit testing at a higher pressure at the manufacturer's option. The hydrostatic test pressure shall be maintained for not less than 5 s for all sizes.

12. Nondestructive Examination

12.1 *General*—The full length of each longitiudinal, helical and skelp end weld shall be subjected to ultrasonic inspection in accordance with 12.3, in combination with radiography in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Paragraph UW51. Radiographic inspection shall include at least 8 in. [200 mm] of weld from each pipe end.

12.2 All required nondestructive examination (NDE) shall be performed after hydrostatic test, except for the nondestructive examination (NDE) of jointer welds and the radiographic inspection of pipe ends.

12.3 *Ultrasonic Inspection*—Any equipment utilizing ultrasonic principles and capable of continuous and uninterrupted inspection of the weld seam shall be used. The equipment shall be checked with an applicable reference standard, as described in 12.3.1 at least once every working turn or not more than 8 hours to demonstrate the effectiveness of the inspection procedures. The equipment shall be adjusted to produce well defined indications when the reference standard is scanned by the inspection unit in a manner simulating inspection of the product.

12.3.1 *Reference Standards*—Reference standards shall have the same diameter and thickness as the product inspected, and may be of any convenient length as determined by the pipe manufacturer. Reference standards shall be either full sections or coupons taken from the pipe. The reference standard shall contain machined notches or a drilled hole, with the following dimensions:

Parallel Sided Notch (A)	Drilled Hole
Depth: 5 % t ± 15 % with min of 0.012 ± 0.002 in. [0.3 ± 0.05 mm]	1⁄16 in. [1.6 mm] diameter
Width: 0.04 in. [1 mm] max	
Lengt: 2 in. [50 mm] min at full depth	

NOTE 1—The reference discontinuities defined herein are convenient standards for calibration of nondestructive testing equipment. The dimensions of these discontinuities should not be construed as the minimum size imperfection detectable by such equipment.

12.3.2 *Surface Condition, Operator Qualifications*—Extent of Examination, and Standardization Procedure– Surface condition, extent of examination, operator qualifications, and standardization procedure shall be in accordance with the requirements of Specification A 450/A 450M.

12.3.3 *Acceptance Limits*—Table 2 gives the height of acceptance limit signals in percent of the height of signals produced by the reference discontinuities. Imperfections in the weld seam that produce a signal greater than the acceptance limit given in Table 2 shall be considered defects.

12.4 *Disposition of NDE Defects*—Pipe that has been rejected in accordance with the provisions of 12.1 or 12.3 shall be given one of the following dispositions:

12.4.1 The pipe length shall be rejected.

12.4.2 The portion of the pipe containing the defect shall be cut off.

12.4.3 The defect shall be removed by grinding, provided that the remaining wall thickness is within specified limits.

12.4.4 The area of the pipe containing the defect shall be repaired by welding.

13. Number of Tests

13.1 Tensile testing of the pipe body, longitudinal welds, and helical welds shall be performed on a test lot basis with a lot size of one sample for each lot of 100 joints of pipe or less.

13.2 Tensile testing of skelp end welds shall be performed at a frequency of one test per lot of 100 lengths containing skelp end welds.

TABLE 2 Acceptance Limits

Top of Notch	Size of Hole		Acceptance Limit
	in.	mm	Signal, %
A	1⁄16	1.6	100

13.3 The guided bend test specimens shall be taken from each lot of 50 lengths or less of each combination of specified outside diameter, specified wall thickness, and grade.

13.4 Charpy V-notch test frequency shall be one set of specimens for each 100 joint test lot, except for skelp end welds, which shall be tested one for each 100 pipe containing such end welds.

14. Test Methods

14.1 The test specimens and the tests required by this specification shall conform to those described in Test Methods and Definitions A 370.

15. Dimensions and Weights [Masses] Per Unit Length

15.1 The dimensions and weights [masses] per unit length of some of the pipe sizes included in this specification are shown in ASME B36.10M. The weight [mass] per unit length of pipe having intermediate diameter or wall thickness, or both, is determined using the applicable equation in 16.1.

16. Permissible Variations in Weight [Mass] and Dimensions

16.1 *Weight [Mass]*—The weight [mass] of a single length of pipe shall not vary more than +10 % , −3.5 % from its theoretical weight [mass]. Pipe weights [masses] per unit length not listed in ASME B36.10M shall be determined using the following equation:

inch-pound units:

$$W = t\,(D-t) \times 10.69 \tag{6}$$

SI units:

$$W = t\,(D-t) \times 0.024\,66 \tag{7}$$

where:

W = weight [mass] per unit length, lb/ft [kg/m],
D = specified outside diameter, in. [mm], and
t = specified wall thickness, in. [mm].

The weight [mass] of any order item shall not be more than 1.75 % under its theoretical weight.

16.2 *Wall Thickness*—The minimum wall thickness at any point shall not be more than 8 % under the specified wall thickness.

16.3 *Length*—Unless otherwise agreed upon between the purchaser and the manufacturer, pipe shall be furnished in the nominal lengths and within the permissible variations given in Table 3.

16.4 *Diameter*—For pipe sizes larger than NPS 48, the diameter tolerances shall be subject to agreement between the manufacturer and the purchaser. The diameter tolerance within 4 in. [100 mm] of each pipe end shall be −1⁄32 , +3⁄32 in. [−1, +3 mm].

17. End Finish

17.1 Pipe furnished to this specification shall be plain-end beveled with ends beveled to an angle of 30°, +5°, −0°, measured from a line drawn perpendicular to the axis of the pipe, and with a root face of 1⁄16 in. [1.6 mm] ± 1⁄32 in. [0.8 mm], or special plain end, as specified in the purchase order.

TABLE 3 Permissible Variations on Lengths

Nominal Length		Minimum Length		Minimum Avg Length for Each Order Item		Maximum Length	
ft	m	ft	m	ft	m	ft	m
20	[6]	9.0	[2.74]	17.5	[5.33]	22.5	[6.86]
40	[12]	14.0	[4.27]	35.0	[10.67]	45.0	[13.72]
50	[15]	17.5	[5.33]	43.8	[13.35]	55.0	[16.76]
60	[18]	21.0	[6.40]	52.5	[16.00]	65.0	[19.81]
80	[24]	28.0	[8.53]	70.0	[21.34]	85.0	[25.91]

18. Workmanship, Finish and Appearance

18.1 The weld bead shall not extend above the prolongation of the original surface of the pipe by more than ⅛ in. [3.2 mm] for pipe specified wall thickness 0.500 in. [12.7 mm] and smaller, or more than 3⁄16 in. [4.8 mm] for specified wall thicknesses greater than 0.500 in. [12.7 mm]. The weld surface shall not be below a prolongation of the original surface.

18.2 Surface imperfections that penetrate more than 8 % of the nominal wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with surface defects shall be given one of the following dispositions:

18.2.1 The defect shall be removed by grinding, provided that the remaining wall thickness is within specified limits.

18.2.2 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.

18.2.3 The section of the pipe containing the defect shall be cut off within the requirements for length.

18.2.4 The length shall be rejected.

18.3 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of a dispute, the measurement determined by the use of a mechanical caliper shall govern.

18.4 Pipe body repairs by welding are not permitted.

18.5 Repairs of the weld are permissible in accordance with Specification A 530/A 530M except that the repair depth shall not exceed 70 % of the specified wall thickness of the pipe and back-to-back repairs are not permitted. No repair of repair weld is permitted.

18.6 Pipe shall be randomly checked for straightness. Deviation from a straight line shall not exceed 0.2 % of the length.

18.7 The pipe shall contain no dents greater than ¼ in. [6.4 mm], measured as the gap between the lowest point of the dent and a prolongation of the original contour of the pipe. Cold formed dents deeper than ⅛ in. [3.2 mm] shall be free of sharp-bottom gouges. The gouges may be removed by grinding, provided that the remaining wall thickness is within specified limits. The length of the dent in any direction shall not exceed one half the pipe diameter.

19. Jointers

19.1 Jointers may be furnished, subject to agreement between manufacturer and purchaser as to minimum length of each piece and total number of jointers. Circumferential jointer welds shall be made using a procedure qualified in accordance with the requirements of API 1104 or ASME Boiler and Pressure Vessel Code, Section IX and inspected by radiographic or ultrasonic procedures or a combination of both.

20. Certification

20.1 A certified test report shall be furnished.

21. Product Marking

21.1 Each length of pipe shall be legibly marked by stenciling to show: specification number, the name or brand of the manufacturer, the specified outside diameter, the specified wall thickness, the grade, the heat number, and the length. The length shall be marked in feet and tenths of a foot, or metres to two decimal places, as applicable.

21.2 In addition to the requirements of 21.1, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used.

22. Keywords

22.1 black steel pipe; double submerged-arc welded; line pipe

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified in the purchase order.

S1. Drop-Weight Tear Testing

S1.1 The drop-weight tear test shall be conducted in accordance with API RP 5L3.

S1.2 The temperature selected for conducting the drop-weight tear test, the test frequency, and the criteria for acceptance shall be as specified in the purchase order.

Designation: A 999/A 999M – 04a

Standard Specification for General Requirements for Alloy and Stainless Steel Pipe[1]

This standard is issued under the fixed designation A 999/A 999M; 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 a group of general requirements that, unless otherwise specified in an individual specification, shall apply to the ASTM product specifications noted below.

1.2 In the case of conflict between a requirement of a product specification and a requirement of this specification, the product specification shall prevail. In the case of conflict between a requirement of the product specification or a requirement of this specification and a more stringent requirement of the purchase order, the purchase order shall prevail.

Title of Specification	ASTM Designation[3]
Seamless and Welded Austenitic Stainless Steel Pipes	A 312/A 312M
Seamless and Welded Steel Pipe for Low-Temperature Service	A 333/A 333M
Seamless Ferritic Alloy-Steel Pipe for High Temperature Service	A 335/A 335M
Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High-Temperature Service	A 358/A 358M
Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service	A 369/A 369M
Seamless Austenitic Steel Pipe for Use With High Temperature Central-Station Service	A 376/A 376M
Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service	A 409/A 409M
Welded, Unannealed Austenitic Stainless Steel Tubular Products	A 778
Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe	A 790/A 790M
Single- or Double-Welded Austenitic Stainless Steel Pipe	A 813/A 813M
Cold-Worked Welded Austenitic Stainless Steel Pipe	A 814/A 814M
Ferritic/Austenitic (Duplex) Stainless Steel Pipe Electric Fusion Welded with Addition of Filler Metal	A 928/A 928M
Spray-Formed Seamless Austenitic Stainless Steel Pipe	A 943/A 943M
Spray-Formed Seamless Ferritic/Austenitic Stainless Steel Pipe	A 949/A 949M
Austenitic Chromium-Nickel-Silicon Alloy Steel Seamless and Welded Pipe	A 954

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 is to be used independently of the other without combining values in any way. The inch-pound units apply unless the "M" designation (SI) of the product specification is specified in the order.

NOTE 1—The dimensionless designator NPS (nominal pipe size) is used in this standard for such traditional terms as "nominal diameter," "size," " nominal bore," and "nominal size."

1.4 The following precautionary statement pertains only to the test method portion, Section 22, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [4]

A 312/A 312M Specification for Seamless and Welded Austenitic Stainless Steel Pipes
A 333/A 333M Specification for Seamless and Welded Steel Pipe for Low-Temperature Service
A 335/A 335M Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service
A 358/A 358M Specification for Electric-Fusion-Welded Austenitic Chromium-Nickel Stainless Steel Pipe for High-Temperature Service and General Applications
A 369/A 369M Specification for Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 376/A 376M Specification for Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service
A 409/A 409M Specification for Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service
A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

[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 Alloy Steel Tubular Products.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA 999 in Section II of that Code.

[3] These designations refer to the latest issue of the respective specifications. See *Annual Book of ASTM Standards*, Vol 01.01.

[4] 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.

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

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 778 Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products
A 790/A 790M Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe
A 813/A 813M Specification for Single- or Double-Welded Austenitic Stainless Steel Pipe
A 814/A 814M Specification for Cold-Worked Welded Austenitic Stainless Steel Pipe
A 928/A 928M Specification for Ferritic/Austenitic (Duplex) Stainless Steel Pipe Electric Fusion Welded with Addition of Filler Metal
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A 943/A 943M Specification for Spray-Formed Seamless Austenitic Stainless Steel Pipes
A 949/A 949M Specification for Spray-Formed Seamless Ferritic/Austenitic Stainless Steel Pipe
A 954 Specification for Austenitic Chromium-Nickel-Silicon Alloy Steel Seamless and Welded Pipe
A 994 Guide for Editorial Procedures and Form of Product Specifications for Steel, Stainless Steel, and Related Alloys
D 3951 Practice for Commercial Packaging
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing
E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation
E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys
E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *ANSI Standards:*
B36.10 Welded and Seamless Wrought Steel Pipe[5]
B36.19 Stainless Steel Pipe[5]

2.3 *Military Standards:*
MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage[6]
MIL-STD-271 Nondestructive Testing Requirements for Metals[6]
MIL-STD-792 Identification Marking Requirements for Special Purpose Equipment[6]

2.4 *Federal Standard:*
Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products[6]

2.5 *Steel Structures Painting Council:*
SSPC-SP6 Surface Preparation Specification No. 6 Commercial Blast Cleaning[7]

2.6 *ASNT Standards:*
SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing[8]

3. Materials and Manufacture

3.1 The steel shall be made by a suitable steelmaking process.

3.2 If secondary melting, such as electroslag remelting or vacuum remelting, is used, the heat shall be defined as all of the ingots remelted from a single primary heat.

3.3 If steels of different grades are sequentially strand cast, the resultant transition material shall be removed using an established procedure that positively separates the grades.

3.4 If a specific type of melting is required by the purchaser, it shall be specified in the purchase order.

4. Terminology

4.1 *Definitions*:

4.1.1 The definitions in Terminology A 941, except as modified in this specification or in its referenced product specifications, are applicable to this specification.

5. Ordering Information

5.1 It is the responsibility of the purchaser to specify all requirements that are necessary for products ordered under the applicable product specification and this general requirements specification. Such requirements to be considered include, but are not limited to, the following:

5.1.1 ASTM product specification and year-date,

5.1.2 Name of product (for example, stainless steel pipe),

5.1.3 Quantity (feet, metres, or number of pieces),

5.1.4 Method of manufacture, where applicable (seamless or welded),

5.1.5 Specific type of melting, if required (see 3.4),

5.1.6 Grade or UNS number,

5.1.7 Size (NPS and outside diameter and schedule number, average (nominal) wall thickness (see 9.1 and 10.1), or minimum wall thickness (see 9.2 and 10.1.1), or minimum inside diameter (see 11.1)),

5.1.8 Length (specific or random),

5.1.9 End finish,

5.1.10 Optional requirements,

5.1.11 Certification (see Section 25),

5.1.12 Specification designation and year of issue, and

5.1.13 Special requirements or any supplementary requirements, or both.

6. Chemical Composition

6.1 *Chemical Analysis*—Samples for chemical analysis and method of analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

[5] Portions of these standards appear in *ASTM Book of Standards*, Vol 01.01. Full text of these standards is available from American National Standards Institute, 11 West 42nd St., 13th floor, New York, NY 10036.

[6] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[7] Available from Steel Structures Painting Council, 4400 Fifth Ave., Pittsburgh, PA 15213.

[8] Available from American Society for Nondestructive Testing, 1711 Arlington Plaza, P.O. Box 28518, Columbus, OH 43228–0518.

6.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the specified elements. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer shall conform to the requirements specified.

6.2.1 For steels ordered under product specifications referencing this specification of general requirements, the steel shall not contain an unspecified element, other than nitrogen for stainless steels, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation in a table of chemical requirements within any specification listed within the scope as being covered by this specification.

6.3 *Product Analysis*—Product analysis requirements and options, if any, shall be as contained in the applicable product specification.

7. Mechanical Properties

7.1 *Method of Mechanical Tests*—The specimens and mechanical tests required shall be in accordance with Test Methods and Definitions A 370, especially Annex A2 thereof.

7.2 Specimens shall be tested at room temperature.

7.3 Small or subsize specimens as described in Test Methods and Definitions A 370 may be used only when there is insufficient material to prepare one of the standard specimens. When using small or subsize specimens, the largest one possible shall be used.

8. Tensile Requirements

8.1 The material shall conform to the requirements as to tensile properties in the applicable product specification.

8.2 The yield strength, if specified, shall be determined corresponding to a permanent offset of 0.2 % of the gage length or to a total extension of 0.5 % of the gage length under load.

8.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than ¾ in. [19.0 mm] from the center of the gage length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

9. Permissible Variation in Mass for Seamless Pipe

9.1 Except as allowed by 9.2, the mass of any length of seamless pipe in sizes NPS 12 and smaller shall not vary more than 10 % over or more than 3.5 % under that specified. For pipe in sizes larger than NPS 12, the mass of any length of pipe shall not vary more than 10 % over or more than 5 % under that specified. Unless otherwise specified, the mass of lengths of pipe in sizes NPS 4 and smaller shall be determined separately or in convenient lots; the mass of lengths of pipe in sizes larger than NPS 4 shall be determined separately.

9.2 *Minimum Wall*—If the wall thickness of the pipe is specified as minimum wall in the purchase order, the mass of any length of seamless pipe shall not vary more than 16 % over that calculated in accordance with 14.3. Unless otherwise specified, the mass of pipe in sizes NPS 4 and smaller shall be determined separately or in convenient lots; the mass of pipe in sizes larger than NPS 4 shall be determined separately.

9.3 The specified mass of pipe shall be determined by multiplying its specified or calculated mass per unit length (see 14.3) by its measured length.

10. Permissible Variations in Wall Thickness

10.1 *Seamless and Welded*—Except as required by 10.1.1, the minimum wall thickness at any point shall not be more than 12.5 % under the nominal wall thickness specified. The minimum wall thickness on inspection is shown in Table X1.1.

10.1.1 *Minimum Wall*—If the wall thickness of the pipe is specified as minimum wall in the purchase order, there shall be no variation under the specified wall thickness.

10.2 *Forged and Bored*—The wall thickness shall not vary over that specified by more than ⅛ in. [3.2 mm]. There shall be no variation under the specified wall thickness.

10.3 *Cast*—The wall thickness shall not vary over that specified by more than 1⁄16 in. [1.6 mm]. There shall be no variation under the specified wall thickness.

11. Permissible Variations in Inside Diameter

11.1 *Forged and Bored, and Cast*—The inside diameter shall not vary under that specified by more than 1⁄16 in. [1.6 mm]. There shall be no variation over the specified inside diameter.

12. Permissible Variation in Outside Diameter

12.1 Variations in outside diameter, unless otherwise agreed upon, shall not exceed the limits given in Table 1. The tolerances for outside diameter include ovality, except as provided for in 12.2 and 12.2.1. (See Note 2.)

12.2 For thin-wall pipe, defined as pipe having a wall thickness of 3 % or less of the specified outside diameter, the diameter tolerance of Table 1 is applicable only to the mean of the extreme (maximum and minimum) outside diameter readings in any one cross-section.

12.2.1 For thin-wall pipe, the difference in extreme outside readings (ovality) in any one cross-section shall not exceed 1.5 % of the specified outside diameter.

NOTE 2—Thin-wall pipe usually develops significant ovality (out-of-roundness) during final annealing, straightening, or both. The diameter

TABLE 1 Permissible Variations in Outside Diameter

NPS Designator	Permissible Variations in Outside Diameter			
	Over		Under	
	in.	mm	in.	mm
⅛-1½ , incl	1⁄64 (0.015)	0.4	1⁄32 (0.031)	0.8
Over 1½ to 4, incl	1⁄32 (0.031)	0.8	1⁄32 (0.031)	0.8
Over 4 to 8, incl	1⁄16 (0.062)	1.6	1⁄32 (0.031)	0.8
Over 8 to 18, incl	3⁄32 (0.093)	2.4	1⁄32 (0.031)	0.8
Over 18 to 26, incl	⅛ (0.125)	3.2	1⁄32 (0.031)	0.8
Over 26 to 34, incl	5⁄32 (0.156)	4.0	1⁄32 (0.031)	0.8
Over 34 to 48, incl	3⁄16 (0.187)	4.8	1⁄32 (0.031)	0.8

tolerances given in Table 1 are usually not sufficient to provide for additional ovality expected in thin-wall pipe.

13. Permissible Variations in Length

13.1 *Seamless and Welded (No Filler Metal Added)*—If specific cut lengths of 24 ft [7.3 m] or less are ordered, no length of pipe shall be under the length specified or more than ¼ in. [6 mm] over that specified.

13.1.1 Permissible variations in length for lengths greater than 24 ft [7.3 m] shall be subject to agreement between the manufacturer and purchaser.

13.2 *Forged and Bored, Cast, and Cast Cold-Wrought*—If specific cut lengths are ordered, no length of pipe shall be under the length specified or more than ⅛ in. [3 mm] over that specified.

13.3 For pipe ordered to random lengths, the lengths and variations shall be agreed upon between the manufacturer and purchaser.

13.4 No girth welds are permitted unless agreed upon by the manufacturer and purchaser.

14. Mass per Unit Length

14.1 A system of standard pipe sizes has been approved by the American National Standards Institute as ANSI B36.10 and B36.19. The standard sizes do not prohibit the production and use of other sizes of pipe produced to the various product specifications referenced in 1.1. (See Note 3.)

14.2 For nonstandard sizes of pipe, the calculated mass per unit length shall be determined using the following equation:

$$M = C(D-t)t \tag{1}$$

where:

C = 10.69 [0.02466],
M = mass per unit length, lb_m/ft [kg/m],
D = specified or calculated (from specified inside diameter and wall thickness) outside diameter, in. [mm], and
t = specified wall thickness, in. (to 3 decimal places) [mm to 2 decimal places].

14.3 When minimum wall thickness is specified in the purchase order, the calculated mass per unit length shall be determined using Eq 1, obtaining from Table X1.1 the nominal wall thickness, t, corresponding to that minimum wall.

NOTE 3—The mass per unit length values given in the American National Standards and the calculated masses per unit length determined using Eq 1 are based upon carbon steel pipe. The mass per unit length of pipe made of ferritic stainless steels may be up to about 5 % less, and that made of austenitic stainless steel up to about 2 % greater, than the values given.

15. Ends

15.1 Unless otherwise specified, the pipe shall be furnished with plain ends. All burrs at the ends of the pipe shall be removed.

16. Straightness

16.1 The finished pipe shall be reasonably straight.

16.2 For metal-arc welded pipe, the maximum deviation from a 10-ft [3.0-m] straightedge placed so that both ends are in contact with the pipe shall be ⅛ in. [3.2 mm]. For metal-arc welded pipe with lengths shorter than 10 ft [3.0 m], this maximum deviation shall be prorated with respect to the ratio of the actual length to 10 ft [3.0 m].

17. Repair by Welding

17.1 Repair by welding of defects in seamless pipe (including centrifugally cast pipe and forged and bored pipe) and of plate defects in welded pipe and, if specifically stated by the applicable product specification, weld seam defects in welded pipe shall be permitted subject to the approval of the purchaser and with the further understanding that the composition of the deposited filler metal shall be suitable for the composition being welded. Defects shall be thoroughly chipped or ground out before welding and each repaired length shall be reheat treated or stress relieved as required by the applicable product specification. Each length of repaired pipe shall be nondestructively tested as required by the applicable product specification.

17.2 Repair welding shall be performed using procedures and welders or welding operators that have been qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

18. Retests

18.1 If the results of the qualification tests of any lot do not conform to the requirements specified in the applicable product specification, retests are permitted on additional lengths of pipe of double the original number from the same lot, each of which shall conform to the requirements specified. Only one retest of any lot is permitted. Nonconformance of the retest is cause for the rejection of the lot.

18.2 Any individual length of pipe that meets the test requirements is acceptable. It is permitted to retest individual lengths that do not conform to the test requirements, provided that the reason for nonconformance is established and the nonconforming portion is removed.

19. Retreatment

19.1 If individual lengths of pipe selected to represent any lot fail to conform to the test requirements, the lot represented may be reheat treated and resubmitted for test. The manufacturer may reheat treat the pipe, but not more than twice, except with the approval of the purchaser.

20. Test Specimens

20.1 Test specimens shall be taken from the ends of finished pipe prior to any forming operations, or being cut to length.

20.2 Specimens cut either longitudinally or transversely shall be acceptable for the tension test.

20.3 If any test specimen shows flaws or defective machining, the specimen may be discarded and another substituted.

21. Flattening Test Requirements

21.1 *Seamless and Centrifugally Cast Pipe*—A section of pipe not less than 2½ in. [60 mm] in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, no cracks or breaks on the inside, outside, or end surfaces, except as allowed by 21.3.4, shall occur before the distance between the plates is less than the value of H calculated as follows:

$$H = (1+e)t/(e+t/D) \quad (2)$$

where:

H = distance between flattening plates, in. [mm],
t = specified wall thickness, in. [mm],
D = specified outside diameter, outside diameter corresponding to specified ANSI pipe size, or outside diameter calculated by adding $2t$ (as defined above) to the specified inside diameter in. [mm], and
e = deformation per unit length (constant for a given grade of steel, 0.07 for medium carbon steel (maximum specified carbon 0.19 % or greater), 0.08 for ferritic alloy steel, 0.09 for austenitic steel, and 0.09 for low-carbon steel (maximum specified carbon 0.18 % or less)).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the specimen meet.

21.2 *Welded Pipe*—A section of welded pipe not less than 4 in. [100 mm] in length shall be flattened cold between parallel plates in two steps. The weld shall be placed at 90° from the direction of the applied force (at the point of maximum bending). During the first step, which is a test for ductility, no cracks or breaks on the inside or outside surfaces, except as provided for in 21.3.4, shall occur before the distance between the plates is less than the value of H calculated by Eq 2. During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the specimen meet.

21.3 *Seamless, Centrifugally Cast, and Welded Pipe*:

21.3.1 Evidence of laminated or defective material or weld that is revealed at any time during the entire flattening test shall be cause for rejection.

21.3.2 Surface imperfections not evident in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

21.3.3 Superficial ruptures resulting from surface imperfections shall not be a cause for rejection.

21.3.4 When low D-to-t ratio tubular products are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than 10.

22. Nondestructive Test Requirements

22.1 If required by the applicable product specification or the purchase order, the pipe shall be tested by the hydrostatic test (see 22.2) or by the nondestructive electric test (see 22.3).

22.2 *Hydrostatic Test*:

22.2.1 Except as allowed by 22.2.2 and 22.2.3, each length of pipe shall be tested by the manufacturer to a hydrostatic pressure that will produce in the pipe wall a stress not less than 60 % of the specified minimum yield strength for ferritic alloy steel and stainless steel pipe, or 50 % of the specified minimum yield strength for austenitic alloy and stainless steel pipe and for ferritic/austenitic stainless steel pipe. The test pressure or stress shall be determined using the following equation:

$$P = 2St/D \text{ or } S = PD/2t \quad (3)$$

where:

P = hydrostatic test pressure in psi [MPa],
S = pipe wall stress in psi or [MPa],
t = specified wall thickness, nominal wall thickness according to specified ANSI schedule number, or 1.143 times the specified minimum wall thickness, in. [mm], and
D = specified outside diameter, outside diameter corresponding to specified ANSI pipe size, or outside diameter calculated by adding $2t$ (as defined above) to the specified inside diameter, in. [mm].

22.2.1.1 The hydrostatic test pressure determined by Eq 3 shall be rounded to the nearest 50 psi [0.5 MPa] for pressures below 1000 psi [7 MPa], and to the nearest 100 psi [1 MPa] for pressures 1000 psi [7 MPa] and above. The hydrostatic test may be performed prior to cutting to final length, or prior to upsetting, swaging, expanding, bending, or other forming operations.

22.2.2 Regardless of pipe-wall stress-level determined by Eq 3, the minimum hydrostatic test pressure required to satisfy these requirements need not exceed 2500 psi [17.0 MPa] for outside diameters (see D in 22.2) of 3.5 in. [88.9 mm] or less, or 2800 psi [19.0 MPa] for outside diameters over 3.5 in. [88.9 mm]. This does not prohibit testing at higher pressures at the option of the manufacturer or as allowed by 22.2.3.

22.2.3 With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements of 22.1 or22.2, or both, may be stated in the purchase order.

22.2.4 The test pressure shall be held for a minimum of 5 s. For welded pipe, the test pressure shall be held for a time sufficient to permit the entire length of the welded seam to be inspected.

22.2.5 The hydrostatic test may not be capable of testing the end portion of the pipe. The length of pipe that cannot be tested shall be determined by the manufacturer and, if specified in the purchase order, reported to the purchaser.

22.3 *Nondestructive Electric Test*:

22.3.1 Each pipe shall be examined with a nondestructive test in accordance with Practices E 213, E 309, E 426, or E 570. Unless specifically called out by the purchaser, the selection of the nondestructive electric test shall be at the option of the manufacturer. Upon agreement between the purchaser and the manufacturer, Practice E 273 shall be employed in addition to one of the full periphery tests. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

22.3.2 The following information is for the benefit of the user of this specification:

22.3.2.1 The reference discontinuities defined in 22.3.8.2-22.3.8.7 are convenient standards for the standardization of nondestructive testing equipment. The dimensions of such reference discontinuities should not be construed as the minimum size imperfection detectable by such equipment.

22.3.2.2 The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented imperfections. It should be recognized that different techniques should be used to detect differently oriented imperfections. The examination may not detect short deep imperfections.

22.3.2.3 The eddy-current testing (ET) referenced in this specification, (see Practices E 426 and E 309), has the capability of detecting significant imperfections, especially of the short abrupt type. The sensitivity of this test decreases with wall thickness over 0.250 in. (6.4 mm).

22.3.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented imperfections; however, sensitivity of the test to various types of imperfections is affected by the calibration, and different techniques should be employed to detect differently oriented imperfections.

22.3.2.5 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of imperfections that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

22.3.3 *Time of Examination*:

22.3.3.1 Nondestructive testing for specification acceptance shall be performed after all mechanical processing, heat treatments, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

22.3.4 *Surface Condition*:

22.3.4.1 All surfaces shall be free of scale, dirt, grease, paint, and other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

22.3.4.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

22.3.5 *Extent of Examination*:

22.3.5.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except as allowed by 22.3.5.2.

22.3.5.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

22.3.6 *Operator Qualifications*:

22.3.6.1 The test unit operator shall be qualified in accordance with SNT-TC-1A, or an equivalent recognized and documented standard.

22.3.7 *Test Conditions*:

22.3.7.1 For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide a good signal-to-noise ratio.

22.3.7.2 The eddy-current coil frequency used shall not exceed the following:

On specified walls up to 0.050 in. [1.3 mm] - 100 kHz
On specified walls up to 0.150 in. [3.8 mm] - 50 kHz
On specified walls equal to or greater than 0.150 in. [3.8 mm] - 10 kHz

22.3.7.3 *Ultrasonic*—For examination by the ultrasonic method, the nominal transducer frequency shall be 2.00 MHz or more and the nominal transducer size shall be 1.5 in [38 mm] or less.

22.3.7.4 If the equipment contains a reject notice filter setting, this shall remain off during calibration and testing unless linearity can be demonstrated at the setting.

22.3.8 *Reference Standards*:

22.3.8.1 Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS, or outside diameter and schedule or wall thickness), surface finish, and heat treatment conditions as the pipe to be examined.

22.3.8.2 *For Ultrasonic Testing*, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of each notch shall not exceed 12.5 % of the specified wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is the greater. The width of the notch shall not exceed twice the depth. Notches shall be placed on both the OD and ID surfaces.

22.3.8.3 *For Eddy-Current Testing*, the reference standard shall contain, at the option of the manufacturer, any one of the following reference discontinuities:

22.3.8.4 *Drilled Hole* —The reference standard shall contain three or more holes, equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. One hole shall be drilled in the weld, if visible. Alternatively, the manufacturer of welded pipe is permitted to drill one hole in the weld and run the calibration standard through the test coils three times, with the weld turned at 120° on each pass. The hole diameter shall not exceed the following:

NPS Designator	Hole Diameter
½	0.039 in. [1.0 mm]
above ½ to 1 ¼	0.055 in. [1.4 mm]
above 1 ¼ to 2	0.071 in. [1.8 mm]
above 2 to 5	0.087 in. [2.2 mm]
above 5	0.106 in. [2.7 mm]

22.3.8.5 *Transverse Tangential Notch*—Using a round tool or a file with a ¼-in. [6.4-mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Such a notch shall have a depth not exceeding 12.5 % of the specified wall thickness of the pipe or 0.004 in. [0.10 mm], whichever is the greater.

22.3.8.6 *Longitudinal Notch*—A notch of 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the pipe axis on the outside surface of the pipe, to have a depth not exceeding 12.5 % of the specified wall thickness of the pipe or 0.004 in. [0.10 mm], whichever is the greater.

22.3.8.7 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

22.3.9 *Standardization Procedure*:

22.3.9.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h.

More frequent standardization may be performed at the manufacturer's option and may be required upon agreement between the purchaser and the manufacturer.

22.3.9.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss, process shutdown, or when a problem is suspected.

22.3.9.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the pipe to be tested.

22.3.9.4 The signal-to-noise ratio for the reference standard shall be 2½ to 1 or greater. Extraneous signals caused by identifiable causes such as dings, scratches, dents, straightener marks, etc., shall not be considered noise. The rejection amplitude shall be adjusted to be at least 50 % of full scale of the readout display.

22.3.9.5 If upon any standardization, the rejection amplitude has decreased by at least 29 % (3 dB) of peak height from the last standardization, the pipe tested since the last calibration shall be rejected or retested for acceptance after the test apparatus settings have been changed, or the transducer(s), coil(s), or sensor(s) have been adjusted, and the test apparatus has been restandardized.

22.3.10 *Evaluation of Imperfections*:

22.3.10.1 Pipes producing a signal equal to or greater than the lowest signal produced by the reference discontinuities shall be identified and separated from the acceptable pipes. The area producing the signal may be reexamined.

22.3.10.2 Such pipes shall be rejected if the test signals were produced by imperfections that cannot be identified or were produced by cracks or crack-life imperfections. Such pipes may be repaired if such repair is permitted by the applicable product specification. To be accepted, a repaired pipe shall pass the same nondestructive test by which it was rejected, and it shall meet the minimum wall thickness requirements of the applicable product specification.

22.3.10.3 If the test signals were produced by visual imperfections such as scratches, surface roughness, dings, straightener marks, cutting chips, steel die stamps, stop marks, or pipe reducer ripple, the pipe is permitted to be accepted based upon visual examination provided that the depth of the imperfection is less than 0.004 in. [0.1 mm] or 12.5 % of the specified wall thickness, whichever is the greater.

22.3.10.4 Rejected pipe may be reconditioned and retested, provided that the wall thickness is not decreased to less than that required by the applicable product specification. The outside diameter at the point of grinding may be reduced by the amount so removed. To be accepted, retested pipe shall meet the test requirement.

22.3.10.5 If the imperfection is explored to the extent that it can be identified as non-rejectable, the pipe may be accepted without further test provided that the imperfection does not encroach on the minimum required wall thickness.

23. Inspection

23.1 The inspector representing the purchaser shall have entry at all times work on the contract of the purchaser is being performed, to all parts of the manufacturer's facilities that concern the manufacture of the product ordered. The manufacturer shall afford the inspector all reasonable facilities to be satisfied that the product is being furnished in accordance with this specification. All required tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the manufacturer's operations.

24. Rejection

24.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based upon the inspection and test method as outlined in the applicable product specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

24.2 Pipe that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the suitability of the pipe. Disposition of such pipe shall be matter for agreement.

25. Certification

25.1 If specified in the purchase order or contract, the manufacturer or supplier shall furnish to the purchaser a certificate of compliance stating that the product was manufactured, sampled, tested, and inspected in accordance with the specification, including year-date, the supplementary requirements, and any other requirements designated in the purchase order or contract, and has been found to meet such requirements. A signature or notarization is not required; however, the document shall be dated and shall clearly identify the organization submitting it.

25.1.1 Notwithstanding the absence of a signature or notarizatin, the certifying organization is responsible for the contents of the document.

25.2 In addition, if specified in the purchase order or contract, the manufacturer or supplier shall furnish to the purchaser a test report that includes the following information and test results, as applicable:

25.2.1 Heat number,

25.2.2 Heat analysis,

25.2.3 Product analysis if specified or required,

25.2.4 Tensile properties,

25.2.5 Width in the gage length, if longitudinal strip tension test specimens were used,

25.2.6 Bend test acceptable,

25.2.7 Flattening test acceptable,

25.2.8 Hydrostatic test pressure,

25.2.9 Nondestructive electric test method,

25.2.10 Impact test results, and

25.2.11 Other test results or information required to be reported by the applicable product specification.

25.3 Test results or information required to be reported by supplementary requirements, or other requirements designated in the purchase order or contract shall be reported but may be reported in a separate document.

25.4 The test report shall include a statement of explanation for the letter added to the specification number marked on the tubes (see 26.5) if all of the requirements of the specification have not been completed. The purchaser must certify that all requirements of the specification have been completed before the removal of the letter (that is, X, Y, or Z).

25.5 A test report, certificate of compliance, or similar document printed from or used in electronic form from an electronic data interchange (EDI) shall be regarded as having the same validity as a counterpart printed in the certifying organization's facility. The content of the EDI transmitted document shall meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for its content.

26. Product Marking

26.1 Each length of pipe shall be legibly marked with the manufacturer's name or brand, the specification number (year of issue not required) and grade. Marking shall begin approximately 12 in. [300 mm] from the end of each length of pipe. For pipe less than NPS 2 and pipe under 3 ft [1 m] in length, the required information may be marked on a tag securely attached to the bundle or box in which the pipes are shipped.

26.2 When pipe marked as specified is rejected, the ASTM designation shall be canceled.

26.3 For austenitic steel pipe, the marking paint or ink shall not contain detrimental amounts of harmful metals, or metal salts, such as zinc, lead, or copper, which cause corrosive attack on heating.

26.4 Pipes that have been weld repaired in accordance with 17.1 shall be marked WR.

26.5 When it is specified that certain requirements of a specification adopted by the ASME Boiler and Pressure Vessel Committee are to be completed by the purchaser upon receipt of the material, the manufacturer shall indicated that all requirements of the specification have not been completed by a letter such as X, Y, or Z, immediately following the specification number. This letter may be removed after completion of all requirements in accordance with the specification. An explanation of specification requirements to be completed is provided in 25.1.

27. Packaging, Marking, and Loading

27.1 If specified in the purchase order, packaging, marking, and loading for shipment shall be in accordance with the procedures of Practices A 700.

28. Government Procurement

28.1 If specified in the contract or purchase order, the following requirements shall be considered in the inquiry, contract, or order for agencies of the U.S. Government where scale-free pipe is required. Such requirements shall take precedence if there is a conflict between these requirements and those of the applicable product specification.

28.2 Pipe shall be ordered to nominal pipe size (NPS) and schedule. Nominal pipe shall be as specified in ANSI B36.10 or B36.19.

28.3 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility for ensuring that all products or supplies submitted to the government for acceptance comply with all requirements of the contract or purchase order. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements; however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the government to accept the material. Except as otherwise specified in the contract or purchase order, the manufacturer may use its own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth if such inspections and tests are deemed necessary to ensure that the products conform to the prescribed requirements.

28.4 *Sampling for Flattening and Flaring Test and for Visual and Dimensional Examination*—Minimum sampling for flattening and flaring tests and visual and dimensional examination shall be as follows:

Lot Size (Pieces per Lot)	Sample Size
2 to 8	Entire Lot
9 to 90	18
91 to 150	12
151 to 280	19
281 to 500	21
501 to 1200	27
1201 to 3200	35
3201 to 10 000	38
10 001 to 35 000	46

In all cases, the acceptance number is zero and the rejection number is one. Rejected lots may be screened and resubmitted for visual and dimensional examination. All defective items shall be replaced with acceptable items prior to lot acceptance.

28.5 *Sampling for Chemical Analysis*—One sample for chemical analysis shall be selected from each two pipes chosen from each lot. A lot shall be all material poured from one heat.

28.6 *Sampling for Tension and Bend Test*—One sample shall be taken from each lot. A lot shall consist of all pipe of the same outside diameter and wall thickness manufactured during an 8-h shift from the same heat of steel, and heat treated under the same conditions of temperature and time in a single charge in a batch-type furnace, or heat treated under the same condition in a continuous furnace, and presented for inspection at the same time.

28.7 *Hydrostatic and Ultrasonic Tests*—Each pipe shall be tested by the ultrasonic (if specified) and hydrostatic tests.

28.8 Pipe shall be free from heavy oxide or scale. The internal surface of hot finished ferritic steel pipe shall be pickled or blast cleaned to a free of scale condition equivalent to the CSa2 visual standard in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

28.9 In addition to the marking required by this specification, each length of pipe NPS ¼ or larger shall be marked, in accordance with FED-STD-183 and MIL-STD-792, with the nominal pipe size, schedule number, length, and heat number or lot identification number.

28.10 Pipe shall be straight to within the tolerance given in Table 2.

28.11 If specified, each pipe shall be ultrasonically examined in accordance with MIL-STD-271, except that the notch depth in the reference standard shall be 5 % of the wall thickness or 0.005 in. [0.1 mm], whichever is the greater. Any pipe that produces an indication equal to or greater than 100 % of the indication from the reference discontinuity shall be rejected.

28.12 The pipe shall be free from repair welds, welded joints, laps, laminations, seams, visible cracks, tears, grooves, slivers, pits, and other imperfections detrimental to the pipe as determined by visual and ultrasonic examination, or alternate tests, as specified.

TABLE 2 Straightness Tolerances

Specified OD, in.^{A}	Specified Wall Thickness, in.^{A}	Maximum Curvature in any 3 ft, in.^{A}	Maximum Curvature in Total Length, in.^{A}
Up to 5.0, incl.	Over 3 % OD to 0.5, incl.	0.030	0.010 × length, ft
Over 5.0 to 8.0, incl.	Over 4 % OD to 0.75 incl.	0.045	0.015 × length, ft
Over 8.0 to 12.75, incl.	Over 4 % OD to 1.0, incl.	0.060	0.020 × length, ft

^{A} 1 in. = 25.4 mm.

28.13 Pipe shall be uniform in quality and condition and have a finish conforming to the best practice for standard quality pipe. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be considered defects if the imperfections are removable within the tolerances specified for wall thickness or 0.005 in. [0.1 mm], whichever is the greater. The bottom of imperfections shall be visible and the profile shall be rounded and faired-in.

28.14 No weld repair by the manufacturer is permitted.

28.15 Preservation shall be level A or commercial, and packing shall be level A, B, or commercial, as specified. Level A preservation and level A or B packing shall be in accordance with MIL-STD-163 and commercial preservation and packing shall be in accordance with Practices A 700 or Practice D 3951.

29. Keywords

29.1 alloy steel pipe; austenitic stainless steel; duplex stainless steel; ferritic/austenitic stainless steel; seamless steel pipe; stainless steel pipe; steel pipe; welded steel pipe

ANNEX

(Mandatory Information)

A1. REQUIREMENTS FOR THE INTRODUCTION OF NEW MATERIALS

A1.1 New materials may be proposed for inclusion in product specifications referencing this general requirements specification subject to the following conditions:

A1.1.1 Application for the addition of a new grade to a specification shall be made to the chairman of the subcommittee that has jurisdiction over that specification.

A1.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable product specification.

A1.1.3 The application shall be accompanied by test data as required by the applicable product specification. Test data from a minimum of three test lots, as defined by the applicable product specification, each from a different heat, shall be furnished.

A1.1.4 The application shall provide recommendations for all requirements appearing in the applicable product specification.

A1.1.5 The application shall state whether the new grade is covered by patent.

APPENDIX

(Nonmandatory Information)

X1. MINIMUM WALL THICKNESS ON INSPECTION FOR NOMINAL (AVERAGE) PIPE WALL THICKNESS

TABLE X1.1 Minimum Wall Thicknesses on Inspection for Nominal (Average) Pipe Wall Thicknesses

NOTE 1—The following equation, upon which this table is based, may be applied to calculate minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:
t_n = nominal (average) wall thickness, in. [mm], and
t_m = minimum wall thicknesses, in. [mm],
The wall thickness in inch-pound units is rounded to three decimal places in accordance with the rounding method of Practice E 29. The wall thickness in SI units is rounded to one decimal place in accordance with the rounding method of Practice E 29.

NOTE 2—This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed herein are necessarily obtainable for the applicable product specification.

Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)	
in.	[mm]	in.	[mm]	in.	[mm]	in.	[mm]	in.	mm	in.	[mm]
0.068	[1.7]	0.060	[1.5]	0.294	[7.5]	0.257	[6.5]	0.750	[19.0]	0.658	[16.6]
0.068	[2.2]	0.077	[2.0]	0.300	[7.6]	0.262	[6.7]	0.812	[20.6]	0.710	[18.0]
0.091	[2.3]	0.080	[2.0]	0.307	[7.8]	0.269	[6.8]	0.843	[21.4]	0.736	[18.7]
0.095	[2.4]	0.083	[2.1]	0.308	[7.8]	0.270	[6.9]	0.854	[21.7]	0.756	[19.2]
0.113	[2.9]	0.099	[2.5]	0.312	[7.9]	0.273	[6.9]	0.875	[22.2]	0.766	[19.5]
0.119	[3.0]	0.104	[2.6]	0.318	[8.1]	0.278	[7.1]	0.906	[23.0]	0.783	[20.1]
0.125	[3.2]	0.109	[2.8]	0.322	[8.2]	0.282	[7.2]	0.937	[23.8]	0.820	[20.8]
0.126	[3.2]	0.110	[2.8]	0.330	[8.4]	0.289	[7.3]	0.968	[24.6]	0.847	[21.5]
0.133	[3.4]	0.116	[2.9]	0.337	[8.6]	0.295	[7.5]	1.000	[25.4]	0.875	[22.2]
0.140	[3.6]	0.122	[3.1]	0.343	[8.7]	0.300	[7.6]	1.031	[26.2]	0.902	[22.9]
0.145	[3.7]	0.127	[3.2]	0.344	[8.7]	0.301	[7.6]	1.062	[27.0]	0.929	[23.6]
0.147	[3.7]	0.129	[3.3]	0.358	[9.1]	0.313	[8.0]	1.083	[27.8]	0.956	[24.3]
0.154	[3.9]	0.135	[3.4]	0.365	[9.3]	0.319	[8.1]	1.125	[28.6]	9.984	[25.0]
0.156	[4.0]	0.136	[3.5]	0.375	[9.5]	0.328	[8.3]	1.156	[29.4]	1.012	[25.7]
0.179	[4.5]	0.157	[4.0]	0.382	[9.7]	0.334	[8.5]	1.218	[30.9]	1.066	[27.1]
0.187	[4.7]	0.164	[4.2]	0.400	[10.2]	0.350	[8.9]	1.250	[31.8]	1.094	[27.8]
0.188	[4.8]	0.164	[4.2]	0.406	[10.3]	0.355	[9.0]	1.281	[32.5]	1.121	[28.5]
0.191	[4.9]	0.167	[4.2]	0.432	[10.4]	0.378	[9.6]	1.312	[33.3]	1.148	[29.2]
0.200	[5.1]	0.175	[4.4]	0.436	[11.1]	0.382	[9.7]	1.343	[34.1]	1.175	[29.8]
0.203	[5.2]	0.178	[4.5]	0.437	[11.1]	0.382	[9.7]	1.375	[34.9]	1.203	[30.6]
0.216	[5.5]	0.189	[4.8]	0.438	[11.1]	0.383	[9.7]	1.406	[35.7]	1.230	[31.2]
0.218	[5.5]	0.191	[4.9]	0.500	[12.7]	0.438	[11.1]	1.436	[36.5]	1.258	[32.0]
0.219	[5.6]	0.192	[4.9]	0.531	[13.5]	0.465	[11.8]	1.500	[36.1]	1.312	[33.3]
0.226	[5.7]	0.196	[5.0]	0.552	[14.0]	0.483	[12.3]	1.531	[38.9]	1.340	[34.0]
0.237	[6.0]	0.207	[5.2]	0.562	[14.3]	0.492	[12.5]	1.562	[39.7]	1.367	[34.7]
0.250	[6.4]	0.219	[5.6]	0.593	[15.1]	0.519	[13.2]	1.593	[40.5]	1.394	[35.4]
0.258	[6.6]	0.226	[5.7]	0.600	[15.2]	0.525	[13.3]	1.750	[44.5]	1.531	[38.9]
0.276	[7.0]	0.242	[6.1]	0.625	[15.9]	0.547	[13.9]	1.781	[45.2]	1.558	[39.6]
0.277	[7.0]	0.242	[6.1]	0.656	[16.6]	0.573	[14.6]	1.812	[46.0]	1.586	[49.3]
0.279	[7.1]	0.244	[6.2]	0.674	[17.1]	0.590	[15.0]	1.968	[50.0]	1.772	[43.7]
0.280	[7.1]	0.245	[6.2]	0.687	[17.4]	0.601	[15.3]	2.062	[52.4]	1.804	[45.8]
0.281	[7.1]	0.246	[6.2]	0.719	[18.3]	0.629	[16.0]	2.343	[59.5]	2.050	[52.1]

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 999/A 999M – 04, that may impact the use of this specification. (Approved July 1, 2004)

(*1*) Added new Terminology section, with reference to Terminology A 941.

(*2*) Added new paragraph 6.2.1 to provide limitation on subsitution of grades within alloy steels and stainless steels.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 999/A 999M – 01, that may impact the use of this specification. (Approved May 1, 2004)

(*1*) General revision for compliance with Terminology A 941 and Guide A 994.

Designation: A 994 – 05

Standard Guide for Editorial Procedures and Form of Product Specifications for Steel, Stainless Steel, and Related Alloys[1]

This standard is issued under the fixed designation A 994; 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 guide covers the editorial form and style for product specifications under the jurisdiction of ASTM Committee A01.

NOTE 1—For standards other than product specifications, such as test methods, practices, and guides, see the appropriate sections of *Form and Style for ASTM Standards* (Blue Book).[2]

1.2 Subcommittees preparing new product specifications or revising existing ones should follow the practices and procedures outlined herein, and be guided by the latest specification covering similar commodities.

1.3 This guide has been prepared as a supplement to the current edition of the Form and Style Manual, and is appropriate for use by the subcommittees to Committee A01. This guide is to be applied in conjunction with the Form and Style Manual.

1.4 If a conflict exists between this guide and the mandatory sections of the current edition of the Form and Style Manual, the Form and Style Manual requirements have precedence. If a conflict exists between this guide and the nonmandatory sections of the current edition of the Form and Style Manual, the guide has precedence.

1.5 When patents are involved, the specifications writer should refer to section F3 of the Form and Style Manual. Also, refer to part F of the Form and Style Manual for trademark information and the safety hazards caveat.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 488/A 488M Practice for Steel Castings, Welding, Qualification of Procedures and Personnel

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

E 6 Terminology Relating to Methods of Mechanical Testing

E 1282 Guide for Specifying the Chemical Compositions and Selecting Sampling Practices and Quantitative Analysis Methods for Metals, Ores, and Related Materials

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

Section IX Welding and Brazing Qualifications

2.3 *Military Standard:*

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage[5]

2.4 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[5]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard*:

3.1.1 For definitions of terms used in this guide, refer to the Form and Style Manual, Terminology A 941, and Terminology E 6.

4. Significance and Use

4.1 The Form and Style Manual provides mandatory requirements and recommended practices for the preparation and content of ASTM specifications. In order to promote consistency in the style and content of product specifications under its jurisdiction, Committee A01 recognizes the need to provide a supplementary document pertaining to the types of products and materials covered by those specifications.

4.2 This guide contains a list of sections to be considered for inclusion in a specification for steel, stainless steel, and related alloy products, and guidance or recommended wording, or both, for such sections.

[1] This guide is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.91 on Editorial.

Current edition approved June 15, 2005. Published June 2005. Originally approved in 1998. Last previous edition approved in 2003 as A 994 – 03.

[2] Available from ASTM International Headquarters, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959.

[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), 345 E. 47th St., New York, NY 10017.

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Phila., PA 19111-5094, Attn: NPODS.

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

4.3 Persons drafting new product specifications, or modifying existing ones, under the jurisdiction of Committee A01, should follow this guide and the requirements of the Form and Style Manual to ensure consistency.

5. Subject Headings of Text

5.1 The various sections of a Committee A01 product specification should be arranged in the following order. Not all of these sections will appear in every specification; however, those used should be listed in the order given. In some cases, a specification may require the addition of a section or sections not listed, in which case they should be inserted in the specification so as to preserve the logical sequence of sections, insofar as possible.

5.2 When only one requirement is used in a section having multiple possible subheadings, that requirement becomes the section heading (for example, Tension Test instead of Mechanical Properties).

- Title
- Designation
- Scope
- Referenced Documents
    - ASTM Standards
    - Other Documents
- Classification
- Terminology
- Ordering Information
- General Requirements
- Materials and Manufacture
    - Melting Practice
    - Mechanical Working Practice
    - Heat Treatment
    - Welding
    - Coatings
- Chemical Composition
    - Heat Analysis
    - Product Analysis
    - Methods of Analysis
- Metallurgical Requirements
    - Grain Size
    - Decarburization
    - Etch Test
    - Micro-cleanliness
    - Hardenability
    - Corrosion Resistance
- Physical Properties
    - Electrical Resistivity
    - Thermal Conductivity
- Mechanical Properties
    - Tension Test
    - Hardness Test
    - Impact Test
    - Bend Test
    - Flattening Test
    - Flange Test
    - Flare Test
    - Proof Load Test
    - Wrap Test
    - Crush Test
    - Coiling Test
- Pressure Test Requirements
    - Hydrostatic Test
    - Air-Under-Water Test
- Nondestructive Test Requirements
    - Magnetic Particle Test
    - Liquid Penetrant Test
    - Radiographic Test
    - Ultrasonic Test
    - Eddy Current Test
    - Flux Leakage Test
- Other Test Requirements
- Dimensions, Mass, and Permissible Variations
    - Flatness
    - Straightness
    - Out-of-roundness
    - Camber
    - Bowing
    - Mating
    - Length
    - Diameter
    - Thickness
- Workmanship, Finish, and Appearance
    - Surface Finish
    - Edges
    - End Finish
- Rework, Retreatment, and Weld Repair
- Sampling
- Number of Tests, Retests, and Resampling
- Specimen Preparation
- Test Methods and Analytical Methods
- Inspection
- Rejection and Rehearing
- Certification
- Product Identification
- Packaging, Marking, and Loading for Shipment
- Keywords
- Supplementary Requirements
- Annexes and Appendixes

6. Section Contents

6.1 *Title*:

6.1.1 The title should be as concise as possible, but complete enough to identify clearly the product covered by the specification. Titles are also used in lists, table of contents, and indexes, and it is most important that they be brief but self-explanatory.

6.1.2 Two methods for establishing wording are considered acceptable and are at the option of the subcommittee.

6.1.3 One is to word as in ordinary conversation with the adjectives first as is normal in the English language. For example, "Standard Specification for Hot-Worked, Hot-Cold-Worked, and Cold-Worked Alloy Steel Plate, Sheet, and Strip for High Strength at Elevated Temperatures." A general scheme for generating titles with this format is:

6.1.3.1 Type of document: "Standard Specification for,"

6.1.3.2 Special treatment of the material, if any: "quenched and tempered," "hot-rolled," "seamless," "welded," etc.,

6.1.3.3 Material type based on chemical composition: "carbon," "high-strength low-alloy," "austenitic stainless," etc.,

6.1.3.4 "Steel,"

6.1.3.5 Product form: "bars," "pressure vessel plate," "casting," "sheet and strip," etc.,

6.1.3.6 Special quality of the product, if any: "with improved toughness," "with mechanical property requirements," "of commercial quality," etc., and

6.1.3.7 Specific application or use of the product, if any: "for machine parts," "for valves," "for low temperature," "for general use," "for corrosive service," etc.

6.1.4 The key word in order of importance concept for specification titles is preferred by many subcommittees because it facilitates accurate indexing and provides rapid identification of specification subject matter. For example, "Standard Specification for Steel Plate, Sheet, and Strip, Alloy, Hot-Worked, Hot-Cold-Worked, and Cold-Worked, for High Strength at Elevated Temperatures." A general scheme for developing a title with this format is:

6.1.4.1 Type of document: "Standard Specification for," 6.1.4.2 "Steel,"

6.1.4.3 Product form: "bars," "pressure vessel plate," "casting," "sheet and strip," etc.,

6.1.4.4 Material type based on chemical composition: "carbon," "high-strength low-alloy," "austenitic stainless," etc.,

6.1.4.5 Special treatment of the material, if any: "quenched and tempered," "hot-rolled," "seamless," "welded," etc.,

6.1.4.6 Special quality of the product, if any: "with improved toughness," "with mechanical property requirements," "commercial quality," etc., and

6.1.4.7 Specific application or use of the product, if any: "for machine parts," "for valves," "for low temperature," "for general use," "for corrosive service," etc.

6.1.5 The use of temperature categories in the titles of specifications should be avoided. When a subcommittee determines that temperature categories must be used in the title of a specific standard, numerical temperature ranges should not be used; the establishment of limits on the use of materials is not the responsibility of Committee A01. When a subcommittee determines that a temperature category must be used in a title, one of the following should be selected: cryogenic, low, ambient, moderate, elevated, or high.

6.2 *Scope*:

6.2.1 When the specification covers multiple grades, classes, types, or combinations thereof, this should be stated in a separate section in the scope. The subdivision grade should be based upon chemical composition, a mechanical property, or application of the product. Further subdivision should be by class, based on some pertinent property or properties, and identified by arabic numbers. The subdivision type should be based on some major property, such as manufacture, product form, or generic classification. The precedence of grade, class, and type is the A01 preferred style, and it should be used in the absence of any established preference.

6.2.2 When a specification has supplementary requirements, the scope should include the following, or similar, statement as a subsection:

> Supplementary requirements of an optional nature are provided for use at the option of the purchaser. The supplementary requirements shall apply only when specified individually by the purchaser in the purchase order or contract.

6.2.3 When a specification is a combined standard, the scope should include the following, or similar, statement as a subsection:

> This specification is expressed in both inch-pound units and in SI units; however, unless the purchase order or contract specifies the applicable *M* specification designation (SI units), the inch-pound units shall apply. 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 may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

6.2.4 In a general requirements specification, the scope should contain the following, or similar, statement:

> In the case of conflict between a requirement of a product specification and a requirement of this specification, the product specification takes precedence. In the case of conflict between a requirement of the product specification and a requirement of this specification and a more stringent requirement of the purchase order or contract, the purchase order or contract takes precedence. The purchase order or contract requirements shall not take precedence if they, in any way, violate the requirements of the product specification or this specification; for example, by the waiving of a test requirement or by making a test requirement less stringent.

6.2.5 *Temperature Categories*:

6.2.5.1 Temperature categories should not be used in the scopes of specifications, because that use may mislead users of standards by creating an implication that the scope reflects engineering judgment on the temperature suitability of products for specific applications. The establishment of temperature limitations on the use of materials is the responsibility of code committees.

6.2.5.2 When a subcommittee determines that temperature categories must be used in a specific standard, numerical temperature ranges should not be used. The categories should be limited to the following: cryogenic, low, ambient, moderate, elevated, or high.

6.2.5.3 When a temperature category is used in the scope of a standard, the scope should cite the property or properties of the specified material that explain the selection of the temperature category with a statement such as:

> Elevated temperatures are temperatures in the range where creep and stress rupture properties are important for the steels in this specification.
>
> Low (or cryogenic) temperatures are temperatures where fracture toughness is important.

6.2.6 Specifications that reference general requirements may include the following statement in the scope:

> The following referenced general requirements are indispensable for the application of this specification: Specification A XXX.

6.2.7 Definitions of the various product forms should be addressed in the section on Terminology, rather than in the Scope section.

6.3 *Referenced Documents*:

Populate this section last, listing in alphanumeric sequence the designation and complete title of all documents referenced within the standard. (The standards listed below are those included in this document in the suggested wording sections.) See section B6 of the Form and Style Manual for more information and for handling of footnotes, year date, and adjuncts.

ASTM Standards:
A 370 Test Method and Definitions for Mechanical Testing of Steel Products[6]
A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment[7]
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[6]
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys[8]
E 6 Terminology Relating to Methods of Mechanical Testing[9]

6.4 *Terminology*— The standards to which the Terminology section should refer for definitions of terms are as follows:

6.4.1

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

E 6 Terminology Relating to Methods of Mechanical Testing

6.5 *Ordering Information*:

6.5.1 In general, the following statement should appear in the Ordering Information section:

It shall be the responsibility of the purchaser to specify all requirements that are necessary for product under this specification. Such requirements to be considered include, but are not limited to, the following:

6.5.2 This statement should be followed by a list of the appropriate items to be shown in the purchase order or contract to adequately describe the product to be supplied under the specification. Each item should contain a parenthetical reference to the number of the appropriate part of the specification to which the item applies, to the extent possible and practicable. Typically, the list would include:

6.5.2.1 Quantity (mass, length, or number of pieces),

6.5.2.2 Name of material,

6.5.2.3 ASTM specification designation and year date to which the product is to be furnished and be certified as meeting,

6.5.2.4 Condition (hot rolled, cold rolled, cold drawn, annealed, heat treated),

6.5.2.5 Grade, class, and type designations,

6.5.2.6 Dimensions,

6.5.2.7 Shape and finish characteristics,

6.5.2.8 Requirements for certifications and for reporting chemical analyses and test results, and

6.5.2.9 Supplementary or other special requirements.

6.6 *General Requirements*:

6.6.1 When a general requirements specification exists for the product specification under consideration, the product specification should contain a General Requirements section, if the general requirements specification is to apply in whole or in part.

6.6.2 Appropriate wording for a General Requirements section is as follows:

Product furnished to this specification shall conform to the requirements of Specification A xxx/A xxxM, including any supplementary requirements indicated in the purchase order or contract. Failure to comply with the general requirements of Specification A xxx/A xxxM constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A xxx/A xxxM, this specification shall prevail.

6.7 *Materials and Manufacture*:

6.7.1 This section addresses such issues as melting, refining, and casting practices; mechanical working requirements; fabrication practices; heat treatment; and surface finishing.

6.7.2 Unless technical considerations dictate otherwise, restrictions should not be placed on manufacturing practices.

6.7.3 When lengthy sections are required describing annealing, heat treating, or other processing, they should be specified in a separate major heading; for example: "8. Heat Treatment."

6.7.4 This section should state briefly the general requirements of the starting materials to be used. Reference appropriate ASTM specifications, if available, and, if appropriate, the process to be followed in manufacture.

6.7.5 When welding is involved in the fabrication of the material or product specified, or to bring a product to the specification requirements, it is necessary to define the processes and procedures that are permitted, either in this section or by reference to other codes and standards. The appropriate process and procedure qualifications may be determined by the intended end use of the part. For example, for castings that are not intended for use under the ASME Boiler and Pressure Vessel Code, procedures and welders shall be qualified under Practice A 488/A 488M. For castings that are intended for use under the ASME Boiler and Pressure Vessel Code, procedures and welders shall be qualified under Section IX of that code.

6.8 *Chemical Composition*:

6.8.1 When limits on chemical composition are required, the section should be stated substantially as, "The steel shall conform to the requirements prescribed in Table X."

6.8.2 This section should include detailed requirements of the chemical composition to which the steel should conform. These requirements should be listed in tabular form and include:

6.8.2.1 Name of each element spelled out,

6.8.2.2 Maximum, minimum, or range for each element,

6.8.2.3 The units applicable (percent or ppm),

6.8.2.4 The UNS number (if available) or common name for each grade of steel, or both, and

6.8.2.5 References to explanatory notes, when applicable.

6.8.3 The preferred order for listing elements for carbon and alloy steels is as follows:

Carbon
Manganese
Phosphorus
Sulfur
Silicon
Nickel
Chromium
Molybdenum
Copper
Titanium
Vanadium
Aluminum
Boron
Columbium (Niobium)

[6] *Annual Book of ASTM Standards*, Vol 01.03.
[7] *Annual Book of ASTM Standards*, Vol 01.05.
[8] *Annual Book of ASTM Standards*, Vol 01.01.
[9] *Annual Book of ASTM Standards*, Vol 03.01.

Columbium + Tantalum
Tantalum
Cobalt
Selenium
Lead
Nitrogen
Others alphabetically

6.8.4 The preferred order for listing elements for stainless steels is as stated in 6.8.3, except list chromium before nickel, nitrogen before copper, and columbium (niobium) before titanium.

6.8.5 *Significant Figures*:

6.8.5.1 It is recommended that Guide E 1282 be consulted as a guide for specifying the chemical compositions for steels.

6.8.5.2 It is recommended that for specifying chemical composition limits the number of figures for each element to the right of the decimal point does not exceed the following:

Chemical Concentration	Composition Limits
Up to 0.010 %	0.XXXX
0.010 to 0.10 %	0.XXX
0.10 to 3.00 %	X.XX
Over 3.00 %	X.X

NOTE 2—This recommendation should be used to reduce the number of significant figures, such as from 18.00 to 18.0 %; however a significant figure should not be added unless there is a technical reason for so doing.

6.8.5.3 For those cases in which the composition range spans 0.010, 0.10, or 3.00 %, the number of figures to the right of the decimal point is to be determined by that indicated by the upper limit of the range.

6.8.5.4 Technical considerations may dictate the employment of less than the maximum number of figures to the right of the decimal point as previously recommended.

6.8.6 A product analysis may be required or be optional in a product specification. When permissible variations for product analysis are included, the following language is recommended:

> The chemical composition determined by product analysis shall conform to the composition limits of Table X, within the permissible variations listed in Table Y.

6.8.7 The section on methods and practices for chemical analysis should be worded as follows:

> Methods and practices relating to chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

6.9 *Mechanical Properties*:

6.9.1 This section should include separate sections, where applicable, for tests such as tension, hardness, and impact. The heading "Mechanical Properties" shall be used only when two or more properties are specified. When only one property is specified, the section shall be given the heading for the specific test, such as "Tension Test" or "Hardness Test."

6.9.2 Each section should include information on general requirements, including, but not limited to, number of samples, sample location (for example, width, length, thickness), specimen orientation, specimen size and shape (when relevant), and retest provisions.

6.9.3 *Test Methods*:

6.9.3.1 Where appropriate, the test methods described in Test Methods and Definitions A 370 should be used and referenced.

6.9.3.2 When test methods other than those contained in Test Methods and Definitions A 370 are required, such methods shall be referenced or described. It is preferable that test methods that have been standardized by a consensus process be used.

6.9.4 When converting specified yield strength and tensile strength requirement values to SI units, convert to the nearest 5 MPa. When converting from SI units, convert to the nearest 1 ksi.

6.9.5 *Specified Values*— The recommended practice for specifying mechanical test requirements is to specify to the nearest value in accordance with Table 1.

6.9.6 The definitions of terms relating to mechanical testing found in Terminology E 6 should be used to the extent possible.

6.10 *Metallurgical Requirements*:

TABLE 1 Recommended Specification Increments for Specifying Mechanical Test Requirements

Test Quantity	Inch-pound Units		SI Units	
	Test Data Range	Specify to	Test Data Range	Specify to
Yield Point, Yield Strength, and Tensile Strength	Under 100 ksi	1 ksi	Under 1000 MPa	5 MPa
	100 ksi and over	5 ksi	1000 MPa and over	10 MPa
Elongation	All values	1 %	All values	1 %
Reduction of Area	All values	1 %	All values	1 %
Impact Energy	Under 30 ft-lbf	1 ft-lbf	Under 40 J	1 J
	30 to 100 ft-lbf	2 ft-lbf	40 to 140 J	5 J
	100 ft-lbf and over	5 ft-lbf	140 J and over	10 J
Lateral Expansion	All	1 mil	All	25 µm
Percent Shear Area	All	5 %	All	5 %
Brinell Hardness	All	[A]	All	[A]
Rockwell Hardness	All scales	1 Rockwell no.	All scales	1 Rockwell no.

[A] Select values corresponding to 0.002 in. [0.05 mm] indentation diameter increments.

6.10.1 This section should include separate sections, where applicable, on grain size, decarburization, etch testing, microcleanliness, hardenability, corrosion resistance, or other metallurgical structure requirements.

6.10.2 Each section should include information on the requirements, including the test methods or reference to a General Requirements specification that contains this information. In addition, each section should contain the number of tests and the test locations.

6.11 *Physical Properties*:

6.11.1 This section should include, where applicable, requirements for physical properties, such as electrical resistivity, thermal conductivity, and other specified physical properties.

6.11.2 Each physical property should be covered in a separate section that includes the acceptance criteria.

6.11.3 The requirements for test procedures should be contained within the section addressing the physical property. The test procedure should either be defined completely within the section or by reference to another test procedure specification. All information required by the referenced specification should be provided.

6.12 *Nondestructive Examination Requirements*:

6.12.1 This section should include, where applicable, requirements for nondestructive examinations, such as magnetic particle tests, liquid penetrant tests, radiographic tests, ultrasonic tests, eddy current tests, and flux leakage tests.

6.12.2 Each nondestructive test should be covered in a separate section that includes the acceptance criteria.

6.12.3 The requirements for test procedures should be contained within the section addressing the nondestructive test. The test procedure should either be defined completely within the section or by reference to another test procedure specification. All information required by the referenced specification should be provided.

6.12.4 Many specifications require the individual performing nondestructive examinations to be certified. Wording similar to the following should be used in such cases:

> Individuals conducting the examinations shall be certified in accordance with (state referenced standard) or an equivalent documented standard acceptable to both purchaser and manufacturer.

6.13 *Other Test Requirements*:

6.13.1 This section should include, where applicable, test requirements that are not addressed elsewhere in this guide.

6.13.2 Each test requirement should be covered in a separate section that includes the acceptance criteria.

6.13.3 The requirements for test procedures should be contained within the section addressing the test requirement. The test procedure should either be defined completely within the section or by reference to another test procedure standard.

6.14 *Dimensions, Mass, and Permissible Variations*:

6.14.1 For clarity, details as to standard shape, mass, and size usually are presented in tabular form with a brief reference in the text. Separate sections with individual tables are preferred. Such a reference may be similar to the following:

> The product form referred to (sheet, strip, bar, etc.) shall conform to the permissible variations in dimension and mass prescribed in Table X.

6.14.2 In tables of permissible variations, the following preferred usage should be adhered to as far as possible:

6.14.2.1 In general headings for columns for thickness, etc., the word "specified" is to be used in preference to "nominal"or "ordered." Where size designations are indeed nominal, for example, for some structural shapes, and for pipe, "nominal" is preferred.

6.14.2.2 The tables should clearly indicate where the various size ranges are divided, for example, ranges from 0 to 10 in., 10 to 20 in., 20 to 30 in. should be more properly stated as:

> 10 in. [250 mm] and under
> Over 10 to 20 in. [250 to 510 mm], incl
> Over 20 to 30 in. [510 to 760 mm], incl

6.15 *Workmanship, Finish, and Appearance*:

6.15.1 *Workmanship*— Examples of workmanship requirements that might be used are presented below. Examples 6.15.1.1 and 6.15.1.2 could apply to any product form. Examples 6.15.1.3-6.15.1.6 could also apply, as appropriate for the product form and quality ordered.

6.15.1.1 For all product forms where surface finish is not specified elsewhere in the specification, "The general appearance with respect to soundness and surface finish shall be consistent with good commercial practice, as determined by visual inspection."

6.15.1.2 For all product forms where surface finish is specified elsewhere in the specification, the statement of 6.15.1.1 should be preceded by the phrase, "In addition to the surface finish requirements of . . ."

6.15.1.3 For bars, "Bars shall be commercially straight and free from twist."

6.15.1.4 For castings, "All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser before manufacture is started. If the pattern is supplied by the purchaser or is produced using a die supplied by the purchaser, the dimensions of the casting shall be as predicated by the pattern or die."

6.15.1.5 For tubular products, "Tubular products shall have smooth ends free from burrs. They shall be free from defects, as determined by visual inspection."

6.15.1.6 For wire, "The wire shall be uniform in diameter and shall be free from splits, scale, and similar imperfections."

6.15.2 *Finish and Appearance*—This section should be used to specify the surface finish requirements, edge requirements, or end finish requirements.

6.15.2.1 Appropriate wording for a section on finish would be, "The types of finish shall be as follows." (This statement is then followed by a list of the finishes and their individual descriptions. For clarity and uniformity, the nomenclature for the finishes and their respective descriptions should be according to recognized industry standards.)

6.15.2.2 When required, a section should be used to specify the type of edge required. Typical wordings for such sections are:

> The type of edge required shall be specified in the purchase order or contract, as follows:
>
> *No. 1 Edge*—An edge of a specified contour (round or square) that is produced when a very accurate width is required or when an edge finish suitable for electroplating is required, or both.

No. 5 Edge—An approximately square edge produced from slit edge material on which the burr is eliminated by rolling or filing.

Cut Edge—An approximately square edge resulting from the cutting of flat-rolled steel into one or more desired widths by means of rotary knives (slit edge) or blade shears (sheared edge).

6.16 *Rework and Retreatment*:

6.16.1 This section should be used, when appropriate, to provide for rework, such as by grinding or repair welding, or retreatment of product represented by tests or inspections that fail to meet the requirements of the specification. Any limitations on the extent of such rework or the number of retreatments should be addressed in this section.

6.16.2 When welding is permitted to bring a deficient product to the specification requirements, it is necessary to define the processes and procedures that may be used, either in this section or by reference to other codes and standards. The appropriate process and procedure qualifications may be determined by the intended end use of the part. For example, for castings that are not intended for use under the ASME Boiler and Pressure Vessel Code, procedures and welders shall be qualified under Practice A 488/A 488M. For castings that are intended for use under the ASME Boiler and Pressure Vessel Code, procedures and welders shall be qualified under Section IX of that code.

6.17 *Sampling*:

6.17.1 If a sampling section is included, the size, that is, mass, number of pieces, etc., of the lot to be qualified should be described for each required test.

6.17.2 When the qualification of the lot is dependent upon test results from an individual sample or samples, the number of tests necessary to qualify the lot should be defined.

6.17.3 The location of the sample or samples and orientation of the test specimen or specimens should be stated, as well as procedures for acquisition of the sample or samples.

6.17.4 When statistical sampling methods are used to qualify a lot on the basis of an examination of some individual units of the lot, references to appropriate sampling plans and procedures for implementation of such plans should be included in an annex to the standard. The sampling plans should include the lot size, the number of units to be sampled, and the number that must be acceptable for the lot to be qualified.

6.17.5 Specifications may include provisions for the making and testing of new test specimens to provide for occasions when a specimen is damaged by defective machining, or reveals casting imperfections or other imperfections during preparation of the specimens that might cause failure upon testing for reasons not attributable to typical material properties or conditions. For example:

If in the course of preparation, a test specimen is made or found to be defective due to such things as machining errors or the presence of non-typical imperfections in the metal, the specimen may be replaced with another that shall be selected on the same basis as the one discarded.

6.18 *Number of Tests, Retests, and Resampling Procedures*:

6.18.1 This section should address the number of tests for each test required by the specification. It should also cover the allowances for retesting and resampling, if permitted by the specification. For example, retesting might be permitted due to the mechanical failure of a specimen, for example, it broke outside the gage length during a tension test. Resampling is the securing of new samples because the tests failed to meet the limits of the standard but were within prescribed limits that allow resampling. Procedures for dealing with product between the original sample and additional samples should be described.

6.18.2 The number of test units and the number of test specimens necessary to qualify the product should be included, as well as the orientation of such test units or specimens. Following are examples of paragraphs that have been used to define the number, location, and orientation of test specimens:

6.18.2.1 For structural steel plates:

Tension Tests—Orientation—For plates wider than 24 in. [600 mm], test specimens shall be taken such that the longitudinal axis of the specimen is transverse to the final direction of the rolling of the plate. Test specimens for all other products shall be taken such that the longitudinal axis of the specimen is parallel to the final direction of rolling.

Plates Provided from Coils—Two tension test specimens shall be taken from each coil tested. One tension-test specimen shall be taken immediately prior to the first plate produced to the qualifying specification and the second tension test specimen shall be taken from the approximate center lap. . .

6.18.2.2 For high-strength low-alloy sheet and strip:

Location and Orientation—Tension test specimens shall be taken at a point immediately adjacent to the material to be qualified. Tension test specimens shall be taken with the longitudinal axis of the test specimens parallel to the rolling direction (longitudinal test).

6.18.3 If the specification allows retesting, the rules for such retesting and the procedures to be followed should be stated, including the number of additional test specimens required and the limits of acceptance. The following paragraph is an example of a paragraph describing retesting procedures:

If the percentage of elongation of any test specimen is less than specified, and any part of the fracture is more than [nl]P in. [20 mm] from the center of the 2-in. [50-mm] gage length of a specimen, or is outside the middle half of the 8-in. [200-mm] gage length of a specimen, a retest is allowed.

6.18.4 If the specification allows resampling, the rules for such resampling, including disposition of product between the original test and the resample, should be included. The procedures to be followed, including the number of additional test specimens and the acceptance criteria, should be included. The following are examples describing resampling procedures:

If the result for an original tension test specimen is within 2 ksi (14 MPa) of the required tensile strength, resampling is permitted. The new sample shall be taken at random from the lot in question. If the result for this retest specimen meet the specified requirements, the lot shall be accepted.

If the result for an original tension test specimen is more than 2 ksi (14 MPa) from the required tensile strength, resampling is permitted, provided that product produced between the location of the original sample and the new sample is discarded from the lot being qualified. Such discarded product shall not be qualified to meet the specification by the new sample. A total of two resampling efforts shall be permitted. If the lot is resampled, two tests shall be required. The first shall be adjacent to the beginning of the lot to be qualified. If the results of both resampling test specimens meet the specified requirements, the lot shall be accepted.

6.19 *Specimen Preparation*—Specifications requiring the determination of the mechanical properties of the product should include the appropriate paragraphs to adequately describe the preparation of the required test specimens. Below are some examples:

> The tension test specimens shall conform to the appropriate sections of Test Methods and Definitions A 370.
>
> Hardness tests may be made on the grip ends of the tension test specimens before they are subjected to the tension test.
>
> Test coupons, from which tension test specimens are prepared, shall be attached to the castings where practicable. If, in the opinion of the manufacturer, the design of the casting is such that test coupons should not be attached thereon, these coupons shall be cast attached to separately cast blocks. The test coupons from which test specimens are to be prepared shall remain attached to the castings or blocks they represent until submitted for inspection, and shall be heat treated with the castings. Test coupons shall be provided in sufficient numbers to furnish the test specimens required in Section X.

The width of strip for which bend tests can be made is subject to practical limitations on the length of the bend test specimen. For narrow strip, the following widths can be tested:

Strip Thickness, in. [mm] Transverse	Minimum Strip Width and Minimum Specimen Length for Bend Tests, in. [mm][A]
0.100 [2.0] and under	½ [13]
0.101 to 0.140 [2.1 to 3.0], excl.	1 [25]
0.140 [3.0], and over	1 ½ [38]

[A] Bend test specimens for sheet and strip may be of any suitable length over the above minimum length.

6.20 *Inspection*—The following standard wording for this section has been adopted by Committee A01:

> The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to be satisfied that the product is being produced and furnished in accordance with this specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations.

6.21 *Rejection and Rehearing*:

6.21.1 *Rejection*—When a rejection section is to be included, the provisions for rejecting the product should be stated. Examples of rejection paragraphs, which may be used, as appropriate, are:

> Product that is found to be defective subsequent to its acceptance at the manufacturer's works may be rejected, and the manufacturer shall be notified.
>
> Product that is found to be defective following original inspection and acceptance at the manufacturer's works may be rejected, and the manufacturer shall be notified.

6.21.2 *Rehearing*—Provisions should be stated for maintaining samples of product rejected by the purchaser, pending disposition. An example is as follows:

> Samples representing product rejected by the purchaser shall be preserved until disposition of the claim has been agreed to between the supplier and the purchaser.

6.22 *Certification*:

6.22.1 When a specification is to include a certification section, the ordering information section should include 6.5.2.3 and 6.5.2.8 of 6.5.2 of this guide. The following are provided for guidance in preparing a certification section: a given specification could include one or more of the following, as appropriate:

> *Product Marking*—Application of the identification markings, as required under Product Marking, shall constitute certification that the product has been supplied in accordance with the requirements of this specification.
>
> *Certificate of Compliance*—When specified in the purchase order or contract, the producer or supplier shall furnish a certificate of compliance stating that the product was manufactured, sampled, tested and inspected in accordance with this specification (including year date) and any other requirements designated in the purchase order or contract, and has been found to meet such requirements.
>
> *Test Reports*—When specified in the purchase order or contract, test reports shall be furnished to the purchaser containing the results of all tests and chemical analyses required by this specification (including year date), and any other requirements designated in the purchase order or contract.

6.22.2 The certification section could also include one or more of the following, as appropriate:

> A signature or notarization is not required; however, the document shall clearly identify the organization submitting it. Notwithstanding the absence of a signature, the organization submitting the document is responsible for its content.
>
> Copies of the original manufacturer's test report shall be included with any subsequent test report.
>
> A certificate of compliance (or test report) printed from or used in electronic form from an electronic data interchange (EDI) shall be regarded as having the same validity as a counterpart printed in the certifying organization's facility. The content of the EDI transmitted document must conform to any existing EDI agreement between the purchaser and the supplier.

6.23 *Product Identification*—Where identification of individual pieces is required, the product markings must include sufficient attributes to distinguish one piece from another. Even product from the same specification number, type, grade, and class may vary from one heat to the next with respect to chemistry and mechanical properties; and product with all these particularities the same may vary in properties with respect to their origin in the ingot or mold, or due to differences in heat treatment. Accordingly, product markings may need to contain enough designators to provide unique piece identification. The list of markings may be different for different products and may include the number, code, or symbol for the following, as applicable: heat number; specification designation and, if necessary, year date; type; grade; class; lot; manufacturer's name, brand, or trademark; and any additional codes required by the specification.

6.24 *Packaging, Marking, and Loading for Shipment*:

6.24.1 Where appropriate Practice A 700 should be referenced, as follows:

> Where applicable, the packing, marking, and loading methods described in Practice A 700 shall be used.

6.24.2 For U.S. Government procurement, packaging, packing, and marking should be required to be in accordance with MIL-STD-163, to the level specified in the purchase order or contract. Marking for shipment for civil agencies should be required to be in accordance with Fed. Std. 123.

6.25 *Keywords*—This section lists appropriate terms for indexing.

6.26 *Supplementary Requirements*—The following supplementary requirements shall apply only when specified individually by the purchaser in the contract or purchase order.

NOTE 3—Supplementary requirements are not permitted to relax the requirements in the body of the standard.

S1 [Title of the First Supplementary Requirement]
S1.1

6.26.1 *Numbering*:

Numbering of supplementary requirements in General or Common Requirements Documents under the jurisdiction of A01 may start with a number other than S1 per agreement with the Committee on Standards (see COS Minutes from 2/27/02).

6.26.2 *Renumbering*:

Supplementary requirements are normally numbered in sequence. When supplementary requirements are deleted or cancelled, the subcommittee may elect to retain the original requirement number. In this case, a note shall be placed after the number indicating the requirement has been cancelled and, where appropriate, indicating a replacement requirement. This minimizes the impact on specification users who may refer to the requirement.

6.27 *Annexes and Appendixes*—Follow the Form and Style Manual.

6.28 *Summary of Changes*:

6.28.1 A Summary of Changes section shall be included in each specification as an unnumbered section at the end of the document. ASTM Committee on Standards has agreed (see COS Minutes from 9/12/02) that entries to this summary of changes section will be retained for a period of eighteen months to ensure availability. An asterisk shall appear after the Scope (**Scope***) with the following wording at the bottom of the first page:

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

6.28.2 Include this statement, filling in the specification number and year date:

This section identifies the principal changes incorporated since A XXX-XX was issued.

6.28.3 Next list, by section or subsection, changes made since the last issue that may impact the use of the standard. Brief descriptions of the changes and reasons for them may be included.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this guide since the last issue, A 994 – 03, that may impact the use of this guide. (Approved June 15, 2005)

(*1*) Added new paragraph 6.2.6 and renumbered subsequent paragraphs.

Designation: A 989/A 989M – 07

Standard Specification for Hot Isostatically-Pressed Alloy Steel Flanges, Fittings, Valves, and Parts for High Temperature Service[1]

This standard is issued under the fixed designation A 989/A 989M; 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 covers hot isostatically-pressed, powder metallurgy, alloy steel piping components for use in pressure systems. Included are flanges, fittings, valves, and similar parts made to specified dimensions or to dimensional standards, such as in ASME Specification B16.5.

1.2 Several grades of alloy steels are included in this specification.

1.3 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. Unless the order specifies the applicable "M" specification designation (SI units), however, the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in parentheses. 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.

1.6 The following safety hazards caveat pertains only to test methods portions, 8.1, 8.2, and 9.5-9.7 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 275/A 275M Practice for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

B 311 Test Method for Density Determination for Powder Metallurgy (P/M) Materials Containing Less Than Two Percent Porosity

E 165 Test Method for Liquid Penetrant Examination

E 340 Test Method for Macroetching Metals and Alloys

E 606 Practice for Strain-Controlled Fatigue Testing

2.2 *MSS Standard:*

SP 25 Standard Marking System for Valves, Fittings, Flanges, and Unions[3]

2.3 *ASME Specifications and Boiler and Pressure Vessel Codes:*

B16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings [4]

2.4 *ASME Section IX Welding Qualifications:*

SFA-5.5 Specification for Low-Alloy Steel Covered Arc-Welding Electrodes[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *can*, *n*—the container used to encapsulate the powder during the pressure consolidation process that is removed partially or fully from the final part.

3.1.2 *compact*, *n*—the consolidated powder from one can that may be used to make one or more parts.

3.1.3 *consolidation*, *n*—the bonding of adjacent powder particles in a compact under pressure by heating to a temperature below the melting point of the powder.

3.1.4 *fill stem*, *n*—the part of the compact used to fill the can that is not usually integral to the part produced.

3.1.5 *hot isostatic-pressing*, *n*—a process for simultaneously heating and forming a compact in which the powder is contained in a sealed formable enclosure, usually made from metal, and the so-contained powder is subjected to equal

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] 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.

[3] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602, http://www.mss-hq.com.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

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

pressure from all directions at a temperature high enough to permit plastic deformation and consolidation of the powder particles to take place.

3.1.6 *lot*, *n*—a number of parts produced from a single powder blend following the same manufacturing conditions.

3.1.7 *part*, *n*—a single item coming from a compact, either prior to or after machining.

3.1.8 *powder blend*, *n*—a homogeneous mixture of powder from one or more heats of the same grade.

3.1.9 *rough part*, *n*—the part prior to final machining.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify in the purchase order all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (weight or number of parts).

4.1.2 Name of material or UNS number.

4.1.3 ASTM designation and year of issue.

4.1.4 Dimensions (tolerances and surface finishes).

4.1.5 Microstructure examination, if required (5.1.4).

4.1.6 Inspection (14.1).

4.1.7 Whether rough part or finished machined part (8.2.2).

4.1.8 Supplementary requirements, if any.

4.1.9 Additional requirements (see 7.2.1 and 16.1).

4.1.10 Requirement, if any, that the manufacturer shall submit drawings for approval showing the shape of the rough part before machining and the exact location of test specimen material (see 9.3.1).

5. Materials and Manufacture

5.1 *Manufacturing Practice*:

5.1.1 Compacts shall be manufactured by placing a single powder blend into a can, evacuating the can, and sealing it. The can material shall be selected to ensure that it has no deleterious effect on the final product. The entire assembly shall be heated and placed under sufficient pressure for a sufficient period of time to ensure that the final consolidated part meets the density requirements of 8.1.2.1. One or more parts shall be machined from a single compact.

5.1.2 The powder shall be prealloyed and made by a melting method capable of producing the specified chemical composition, such as but not limited to air or vacuum induction melting, followed by gas atomization.

5.1.3 When powder from more than one heat is used to make a blend, the heats shall be mixed thoroughly to ensure homogeneity.

5.1.4 The compact shall be sectioned and the microstructure examined to check for porosity and other internal imperfections and shall meet the requirements of 8.1.3. The sample shall be taken from the fill stem or from a location in a part as agreed upon by the manufacturer and purchaser.

5.1.5 Unless otherwise specified in the purchase order, the manufacturer shall remove the can material from the surfaces of the consolidated compacts by chemical or mechanical methods, such as by pickling or machining. This removal shall be done before or after heat treatment at the option of the manufacturer (see Note 1).

NOTE 1—Often, it is advantageous to leave the can material in place until after heat treatment or further thermal processing of the consolidated compact.

6. Chemical Composition

6.1 The steel both as a blend and as a part shall conform to the requirements for chemical composition prescribed in Table 1. Test Methods, Practices, and Terminology A 751 shall apply.

6.1.1 A representative sample of each blend of powder shall be analyzed by the manufacturer to determine the percentage of elements prescribed in Table 1. The blend shall conform to the chemical composition requirements prescribed in Table 1.

6.1.2 When required by the purchaser, the chemical composition of a sample from one part from each lot of parts shall be determined by the manufacturer. The composition of the sample shall conform to the chemical composition requirements prescribed in Table 1.

6.2 Addition of lead, selenium, or other unspecified elements for the purpose of improving the machinability of the compact shall not be permitted.

6.3 The steel shall not contain an unspecified element, for the ordered grade, to the extent that the steel conforms to the

TABLE 1 Chemical Requirements

UNS Designation	Grade	Composition, %^{A}										
		Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Columbium plus Tantalum	Tantalum, max	Titanium
Alloy Steels												
K90941	9 % chromium	0.15 max	0.30–0.60	0.030	0.030	0.50–1.00	. . .	8.0–10.0	0.90–1.10	. . .	. . .	. . .
K91560	9 % chromium, 1 % molybdenum, 0.2 % vanadium plus columbium and nitrogen	0.08-0.12	0.30–0.60	0.020	0.010	0.20–0.50	0.40 max	8.0–9.5	0.85–1.05	Other Elements Cb 0.06–0.10 N 0.03–0.07 Al 0.04 max V 0.18–0.25		
K31545	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	. . .	2.7–3.3	0.80–1.06	. . .	. . .	. . .
K21590 Class 1	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	. . .	2.00–2.50	0.87–1.13	. . .	. . .	. . .
K21590 Class 3	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	. . .	2.00–2.50	0.87–1.13	. . .	. . .	. . .

^{A} Maximum, unless otherwise specified.

requirements of another grade for which that element is a specified element having a required minimum content.

7. Heat Treatment

7.1 After hot isostatic-pressing, the compacts shall be annealed prior to heat treating in accordance with the requirements of Table 2. At the option of the producer, this anneal shall be a separate operation following powder consolidation or shall be a part of the consolidation process.

7.2 The alloy steels shall be heat treated in accordance with the requirements of 7.1 and Table 2.

7.2.1 *Liquid Quenching*—When agreed to by the purchaser, liquid quenching followed by tempering shall be permitted provided the temperatures in Table 2 for each grade are utilized.

7.2.1.1 *Marking*—Parts that are liquid quenched and tempered shall be marked "QT".

7.3 See Supplementary Requirement S10 if a particular heat treatment method is specified by the purchaser in the purchase order.

7.4 *Time of Heat Treatment*—Heat treatment of the hot isostatically-pressed parts shall be performed before or after machining at the option of the manufacturer.

8. Structural Integrity Requirements

8.1 *Microporosity*:

8.1.1 The parts shall be free of microporosity as demonstrated by measurement of density as provided in 8.1.2 or by microstructural examination as provided in 8.1.3.

8.1.2 *Density Measurement*:

8.1.2.1 The density measurement shall be used for acceptance of material but not for rejection of material. The measured density for each production lot shall exceed 99 % of the density typical of that grade when wrought and in the same heat treated condition as the sample. A production lot that fails to meet this acceptance criterion is permitted, at the option of the producer, to be tested for microporosity in accordance with the microstructural examination as provided in 8.1.3.

8.1.2.2 Density shall be determined for one sample from each production lot by measuring the difference in weight of the sample when weighed in air and when weighed in water and multiplying this difference by the density of water (Archimede's principle). The equipment used shall be capable of determining density within ±0.004 lb/in.^{3} (0.10 g/cm^3). Alternatively, at the option of the producer, it is permitted to use Test Method B 311 to determine the density.

8.1.2.3 At the option of the producer, the density shall be compared to the room temperature density typical of wrought alloy steels or to the density of a wrought reference sample of the same grade heat treated in accordance with the requirements of Table 2 (see Note 2). The typical density for alloy steel in the annealed condition at room temperature is 0.28 lb/in.^{3} (7.8 g/cm^3).

NOTE 2—The actual density of alloy steel varies slightly with composition and heat treatment. For this reason, small differences in the measured density from the typical density for a given grade of steel may be the result of differences in alloy content, heat treatment, or microporosity. When density values are measured that are less than the density typical of a given grade of steel, it is appropriate to examine the sample for microporosity by the more specific metallographic examination procedures.

8.1.3 *Microstructural Examination*:

8.1.3.1 The microstructure when examined at 20-50×, 100-200×, and 1000-2000× shall be reasonably uniform and shall be free of voids, laps, cracks, and porosity.

8.1.3.2 One sample from each production lot shall be examined. The sample shall be taken, at the option of the producer, after hot isostatic-pressing or after final heat treatment. The microstructure shall meet the requirements of 8.1.3.1.

8.1.3.3 If the sample fails to meet the requirements for acceptance, it is permitted to retest each part in the lot. Each part that passes the requirements of 8.1.3.1 shall be accepted.

8.2 *Hydrostatic Tests*—After they have been machined, pressure-containing parts shall be tested to the hydrostatic shell test pressures prescribed in ASME B16.5 for the applicable steel rating for which the part is designed, and shall show no leaks. Parts ordered under these specifications for working pressures other than those listed in the ASME B16.5 ratings shall be tested to such pressures as may be agreed upon between the manufacturer and purchaser.

8.2.1 No hydrostatic test is required for [welding neck] or other flanges. [check terminology]

8.2.2 The compact manufacturer is not required to perform pressure tests on rough parts that are to be finish machined by others. The fabricator of the finished part is not required to pressure test parts that are designed to be pressure-containing only after assembly by welding into a larger structure. The

TABLE 2 Heat Treating Requirements

UNS No.	Heat Treat Type	Austenitizing/Solutioning Temperature, °F [°C]^A	Cooling Media	Quenching, Cool to Below °F [°C]	Tempering Temperature, min °F [°C]
		Alloy Steels			
K90941	anneal	1750 [955]	furnace cool	^{B}	^{B}
	normalize and temper	1750 [955]	air cool	^{B}	1250 [675]
K91560	normalize and temper	1900-2000 [1040-1095]	air cool	^{B}	1350 [730]
K31545	anneal	1750 [955]	furnace cool	^{B}	^{B}
K21590 Class 1,3	anneal	1650 [900]	furnace cool	^{B}	^{B}
	normalize and temper	1650 [900]	air cool	^{B}	1250 [675]

^{A} Minimum unless temperature range is listed.
^{B} Not applicable.

manufacturer of the compacts, however, shall be responsible as required in 15.1 for the satisfactory performance of the parts under the final test required in 8.2.

9. Mechanical Properties

9.1 The material shall conform to the requirements for mechanical properties prescribed in Table 3 at room temperature.

9.2 Mechanical test specimens shall be obtained from production parts or from the fill stems. Mechanical test specimens shall be taken from material that has received the same heat treatment as the parts that they represent. If repair welding is required (see Section 15), the test specimens prior to testing shall accompany the repaired parts if a post weld heat treatment is done.

9.3 For normalized and tempered parts, or quenched and tempered parts, the central axis of the test specimen shall correspond to the ¼ *T* plane or deeper position where *T* is the maximum heat treated thickness of the represented part. In addition, for quenched and tempered parts, the midlength of the test specimen shall be at least *T* from any second heat treated surface. When the section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location, as agreed to by the purchaser and the supplier.

9.3.1 Alternatively, with prior approval of the purchaser, it is permitted to take the test specimen for the steel parts at a depth (*t*) corresponding to the distance from the area of significant stress to the nearest heat treated surface and at least twice this distance (2*t*) from any second surface. The test depth, however, shall not be nearer to one treated surface than ¾ in. (19 mm) and to the second treated surface than 1½ in. (38 mm). This method of test specimen location would normally apply to complex parts, or parts with thick cross-sectional areas where ¼ *T* and *T* testing (see 9.3) is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

9.4 For annealed alloy steels the test specimen may be taken from any convenient location.

9.5 *Tension Test*:

9.5.1 One tension test shall be made for each production lot in each heat treatment charge.

9.5.1.1 When the heat treating cycles are the same and the furnaces (either batch or continuous type) are controlled within ±25 °F [±14 °C] and equipped with recording pyrometers so that complete records of heat treatment are available, then only one tension test from each production lot of each type of part, and section size is required instead of one test from each production lot in each heat-treatment charge. The term "type," as used here, designates a characteristic shape of a part, such as flange, elbow, tee, and so forth.

9.5.1.2 The tension test specimen shall be made from material accompanying the parts in final heat treatment.

9.5.2 Testing shall be performed in accordance with Test Methods and Definitions A 370 using the largest feasible of the round specimens. The gage length for measuring elongation shall be four times the diameter of the test section.

9.6 *Hardness Tests*:

9.6.1 When two or more parts are produced, a minimum of two pieces per batch or continuous run as defined in 9.6.2 shall be hardness tested in accordance with Test Methods and Definitions A 370 to ensure that the parts are within the hardness limits given for each grade in Table 3. When only one part is produced, it shall be hardness tested as required. The purchaser is permitted to verify that the requirement has been met by testing at any location on any part, provided such testing does not render the part useless.

9.6.2 When the reduced number of tension tests permitted by 9.5.1.1 is applied, additional hardness tests shall be made on parts or samples as defined in 9.2 distributed throughout the charge. At least eight samples shall be checked from each batch load and a least one check/h shall be made from a continuous run. When the furnace batch charge is less than eight parts, each part shall be checked. If any hardness test result falls outside the prescribed limits, the entire lot of parts shall be reheat treated and the requirements of 9.5.1 shall apply.

9.7 *Fatigue Tests*—When specified in the order, the fatigue strength of alloy steel, except UNS K91560, components intended for service above 800 °F [425 °C] and for UNS K91560 components intended for service above 1000 °F [540 °C] shall be tested in accordance with the requirements of Supplementary Requirement S11.

10. Product Analysis

10.1 The purchaser is permitted to make a product analysis on parts supplied to this specification. Samples for analysis shall be taken from midway between the center and surface of solid parts, midway between the inner and outer surfaces of hollow parts, midway between the center and surface of full-size prolongations, or from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 1 with the tolerances as stated in Table 4 or Table 5.

TABLE 3 Tensile and Hardness Requirements

UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa][A]	Elongation in 2 in. [50 mm] or 4*D*, min, %	Reduction of Area, min, %	Brinell Hardness Number
Alloy Steels					
K90941	85 [585]	55 [380]	20.0	40.0	179–217
K91560	85 [585]	60 [415]	20.0	40.0	248 max
K31545	75 [515]	45 [310]	20.0	30.0	156–207
K21590 Class 1	60 [415]	30 [205]	20.0	35.0	170 max
K21590 Class 3	75 [515]	45 [310]	20.0	30.0	156–207

[A] Determined by the 0.2 % offset method. For ferritic steels only, the 0.5 % extension-under-load method also may be used.

TABLE 4 Product Analysis Tolerances for Alloy Steels with a Maximum Chromium Limit 4 % or More[A]

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	0.030, incl	0.005
	over 0.030 to 0.20 incl	0.01
Manganese	to 1.00, incl	0.03
	over 1.00 to 3.00, incl	0.04
Phosphorus	to 0.040, incl	0.005
Sulfur	to 0.030, incl	0.005
Silicon	to 1.00, incl	0.05
Chromium	over 4.00 to 10.00, incl	0.10
	over 10.00 to 15.00, incl	0.15
Nickel	to 1.00, incl	0.03
	over 1.00 to 5.00, incl	0.07
Molybdenum	to 0.20 incl	0.01
	over 0.20 to 0.60, incl	0.03
	over 0.60 to 2.00, incl	0.05
Titanium	all ranges	0.05
Columbium + tantalum	all ranges	0.05
Tantalum	to 0.10, incl	0.02
Cobalt	0.05 to 0.20, incl	0.01[B]
Nitrogen	to 0.19 incl	0.01
Columbium	0.05 to 0.20, incl	0.01
Aluminum	to 0.05 incl	0.01
Vanadium	to 0.10 incl	0.01
	over 0.10 to 0.25 incl	0.02
Cerium	0.03 to 0.08	–0.005 +0.01
Tungsten	to 1.00, incl	0.04
Copper	to 1.00, incl	0.03

[A] This table does not apply to heat analysis.
[B] Product analysis limits for cobalt under 0.05 % have not been established and the producer should be consulted for those limits.

TABLE 5 Product Analysis Tolerances for Alloy Steels with Maximum Chromium Limit Less than 4 %

Element[B]	Limit or Maximum of Specified Ranges, %	Tolerance Over Maximum Limit or Under Minimum Limit for Size Ranges Shown, %[A]			
		100 in.^{2} (6.45× 10^4 mm^2) or less	Over 100 to 200 in.^{2} (1.290 × 10^5 mm^2), incl	Over 200 to 400 in.^{2} (2.581 × 10^5 mm^2), incl	Over 400 in.^{2}
Manganese	to 0.90 incl	0.03	0.04	0.05	0.06
	over 0.90 to 1.00 incl	0.04	0.05	0.06	0.07
Phosphorus	to 0.045 incl	0.005	0.010	0.010	0.010
Sulfur	to 0.045 incl	0.005	0.010	0.010	0.010
Silicon	to 0.40 incl	0.02	0.02	0.03	0.04
	over 0.40 to 1.00 incl	0.05	0.06	0.06	0.07
Nickel	to 0.50	0.03	0.03	0.03	0.03
Chromium	to 0.90 incl	0.03	0.04	0.04	0.05
	over 0.90 to 2.10 incl	0.05	0.06	0.06	0.07
	over 2.10 to 3.99 incl	0.10	0.10	0.12	0.14
Molybdenum	to 0.20 incl	0.01	0.01	0.02	0.03
	over 0.20 to 0.40 incl	0.02	0.03	0.03	0.04
	over 0.40 to 1.15 incl	0.03	0.04	0.05	0.06
Copper	to 1.00 incl	0.03	0.03	0.03	0.03
	over 1.00 to 2.00 incl	0.05	0.05	0.05	0.05
Titanium	to 0.10	0.01	0.01	0.01	0.01
Vanadium	to 0.10 incl	0.01	0.01	0.01	0.01
	0.11 to 0.25 incl	0.02	0.02	0.02	0.02
	0.26 to 0.50 incl	0.03	0.03	0.03	0.03

[A] Cross-sectional area.
[B] Product analysis for carbon, boron, columbium, and calcium shall conform to Table 1.

11. Reheat Treatment

11.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer is permitted to reheat treat the parts and repeat the tests specified in Section 9, but not more than twice.

12. Workmanship, Finish and Appearance

12.1 The parts shall be free of scale, machining burrs, and other injurious imperfections as defined herein. The parts shall have a workmanlike finish and machined surfaces, other than surfaces having special requirements, shall have a surface finish not to exceed 250 AA (arithmetic average) roughness height.

12.2 At the discretion of the purchaser, finished parts shall be subject to rejection if surface imperfections acceptable under 12.4 are not scattered but appear over a large area in excess of what is considered to be a workmanlike finish.

12.3 *Depth of Imperfections*—Linear imperfections shall be explored for depth. When the depth encroaches on the minimum wall thickness of the finished parts, such imperfections shall be considered defects.

12.4 *Machining or Grinding Imperfections Not Classified as Defects*—Surface imperfections not classified as defects shall be treated as follows:

12.4.1 Seams, laps, tears, or slivers not deeper than 5 % of the nominal wall thickness or 1⁄16 in. [1.6 mm], whichever is less, need not be removed. If these imperfections are removed, they shall be removed by machining or grinding.

12.4.2 Mechanical marks or abrasions and pits shall be acceptable without grinding or machining provided the depth does not exceed the limitations in 12.4.1. Imperfections that are deeper than 1⁄16 in. (1.6 mm), but that do not encroach on the minimum wall thickness of the part shall be removed by grinding to sound metal.

12.4.3 When imperfections have been removed by grinding or machining, the outside dimension at the point of grinding or machining may be reduced by the amount removed. Should it be impracticable to secure a direct measurement, the wall thickness at the point of grinding, or at an imperfection not required to be removed, shall be determined by deducting the amount removed by grinding from the nominal finished wall thickness of the part, and the remainder shall not be less than the minimum specified or required wall thickness.

13. Repair by Welding

13.1 Weld repairs shall be permitted (see Supplementary Requirement S7) only with prior approval of the purchaser and with the following limitations and requirements:

13.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

13.1.2 The weld metal shall be deposited using the electrodes specified in Table 6. The electrodes shall be purchased in accordance with ASME Specification SFA-5.5. The submerged arc process with neutral flux, the gas metal-arc welding and gas tungsten-arc welding processes are permitted.

13.1.3 Defects shall be completely removed prior to welding by chipping or grinding to sound metal as verified by

TABLE 6 Repair Welding Requirements

UNS Designation	Electrodes[A]	Preheat and Interpass Temperature Range, °F [°C]	Minimum Post-Weld Heat Treatment Temperature °F [°C]
	Alloy Steels		
K90941	E 505-15 or 16	400-700 [205-370]	1250 [675]
K91650	9 % Cr, 1 % Mo, VCbN	400-700 [205-370]	1300 [705]
K31545	E 9018-B 3	300-600 [150-315]	1250 [675]
K21590 Class 1	E 9018-B 3	300-600 [150-315]	1250 [675]
K21590 Class 3	E 9018-B 3	300-600 [150-315]	1250 [675]

[A] Electrodes shall comply with ASME SFA 5.5.

magnetic particle inspection in accordance with Test Method A 275/A 275M for the alloy steels in this specification, or by liquid penetrant inspection in accordance with Test Method E 165 for all grades.

13.1.4 After repair welding, the welded area shall be ground smooth to the original contour and shall be free of defects as verified by magnetic-particle or liquid-penetrant inspection, as applicable.

13.1.5 The preheat, interpass temperature, and post-weld heat treatment, requirements given in Table 6 shall be met.

13.1.6 Repair by welding shall not exceed 10 % of the surface area of the part. Repair by welding shall not exceed 33⅓ % of the wall thickness of the finished part or ⅜ in. (9.5 mm), whichever is less.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy the inspector that the material is being furnished in accordance with the purchase order. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture unless otherwise agreed upon.

15. Rejection

15.1 Each part that develops defects during shop working operations or in service shall be rejected and the manufacturer notified.

15.2 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon between the manufacturer and the purchaser.

16. Certification

16.1 Test reports are required and shall include certification that all requirements of this specification have been met. The specification designations included on test reports shall include year of issue and revision letter, if any. The manufacturer shall provide the results of all tests required by this specification and the purchase order.

17. Product Marking

17.1 Identification marks consisting of the manufacturer's symbol or name (see Note 3), the blend number, designation of service rating, the specification number, the designation showing the grade of material, and the size shall be legibly stamped on each part or the parts may be marked in accordance with Standard SP 25 of the Manufacturers Standardization Society of the Valve and Fittings Industry, and in such position so as not to injure the usefulness of the part. The specification number marked on the part need not include specification year of issue and revision letter.

NOTE 3—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

17.1.1 Quenched and tempered alloy steel parts shall be marked with the letters "QT" following the specification designation.

17.1.2 Hot isostatically-pressed parts repaired by welding shall be marked with the letter "W" following the specification designation.

17.1.3 When test reports are required, the markings shall consist of the manufacturer's symbol or name, the grade symbol, and such other markings as necessary to identify the part with the test report (17.1.1 and 17.1.2 shall apply).

17.1.4 Hot isostatically-pressed parts meeting all requirements for more than one class or grade are permitted at the option of the producer to be marked with more than one class or grade designation.

17.2 *Bar Coding*—In addition to the requirements in 17.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order that a specific bar coding system be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 alloy steel; chromium-alloy steel; chromium-molybdenum steel; gas-atomized powder; hot isostatically-pressed alloy steel parts; piping applications; pipe fittings, steel; pressure containing parts; steel flanges; steel valves; temperature service applications, elevated; temperature service applications, high

SUPPLEMENTARY REQUIREMENTS

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

S1. Macroetch Test

S1.1 A sample part shall be sectioned and etched to show internal imperfections. The test shall be conducted according to Test Method E 340. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S2. Product Analysis

S2.1 A product analysis in accordance with Section 10 shall be made from one randomly selected part representing each size and type (See 9.5.1.1) of part on the order. If the analysis fails to comply, each part in that lot, at the option of the manufacturer, shall be checked and accepted if the analysis for the part complies with the requirements, or the lot shall be rejected. All results shall be reported to the purchaser.

S3. Tension Tests

S3.1 In addition to the requirements of Section 9, one tension specimen shall be obtained from a representative part from each production lot at a location agreed upon between the manufacturer and the purchaser. The results of the test shall comply with Table 3 and shall be reported to the purchaser.

S4. Magnetic Particle Examination

S4.1 All accessible surfaces of a finished alloy steel part shall be examined by a magnetic-particle method. The method shall be in accordance with Test Method A 275/A 275M. Acceptance limits shall be agreed upon between the manufacturer and purchaser.

S5. Liquid Penetrant Examination

S5.1 All accessible surfaces shall be examined by a liquid penetrant method in accordance with Test Method E 165. Acceptance limits shall be agreed upon between the manufacturer and the purchaser.

S6. Hydrostatic Testing

S6.1 A hydrostatic test at a pressure agreed upon between the manufacturer and the purchaser shall be applied by the manufacturer.

S7. Repair Welding

S7.1 No repair welding shall be permitted without prior approval of the purchaser. If permitted, the restrictions of Section 15 shall apply.

S8. Heat Treatment Details

S8.1 The manufacturer shall furnish a detailed test report containing the information required in 16.1 and shall include all pertinent details of the heat treating cycle given the parts.

S9. Hardness Test

S9.1 Each part shall be hardness tested and shall meet the requirements of Table 3.

S10. Alternate Heat Treatment (Grade K91560)

S10.1 Grade K91560 shall be normalized in accordance with Section 7 and tempered at a temperature, to be specified by the purchaser, less than 1350 °F [730 °C]. It shall be the purchaser's responsibility to subsequently temper at 1350 °F [730 °C] min to conform to the requirements of the specification. All mechanical tests shall be made on material heat treated in accordance with Section 7. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S10" shall be included with the required marking of the part.

S11. Fatigue Acceptance Test

S11.1 For alloy steel, except UNS K91560, components intended for service above 800 °F [425°C], and for UNS K91560 components intended for service above 1000 °F [540 °C] a uniaxial fatigue test shall be performed.

S11.2 The fatigue test shall be performed in air at 1100 °F [595 °C] at an axial strain range of 1.0 % with a one hour hold period at the maximum positive strain point in each cycle. Test specimen location and orientation shall be in accordance with the general guidance of Test Methods and Definitions A 370 and the applicable product specifications. Testing shall be conducted in accordance with Practice E 606. The test shall exceed 200 cycles without fracture or a 20 % drop in the load range.

S11.3 Failure to meet this requirement shall be cause for rejection of all parts from that powder blend.

S11.4 Test frequency shall be the same as for tension tests (see 9.5). Retesting is permitted. Two additional specimens produced from the same powder blend shall be tested and both specimens must pass the cyclic life requirement. Further retests are not permitted.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 989/A 989M – 05, that may impact the use of this specification. (Approved September 1, 2007)

(*1*) Corrected Type for K21590 in Table 3.

Designation: A 988/A 988M – 07

Standard Specification for Hot Isostatically-Pressed Stainless Steel Flanges, Fittings, Valves, and Parts for High Temperature Service[1]

This standard is issued under the fixed designation A 988/A 988M; 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 covers hot isostatically-pressed, powder metallurgy, stainless steel piping components for use in pressure systems. Included are flanges, fittings, valves, and similar parts made to specified dimensions or to dimensional standards, such as in ASME specification B16.5.

1.2 Several grades of martensitic, austenitic, age hardening, and austenitic-ferritic stainless steels are included in this specification.

1.3 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. Unless the order specifies the applicable "M" specification designation (SI units), however, the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in parentheses. 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.

1.6 The following safety hazards caveat pertains only to test methods portions 8.1, 8.2, 9.5-9.7, and Section 10 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A 275/A 275M Practice for Magnetic Particle Examination of Steel Forgings
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 745/A 745M Practice for Ultrasonic Examination of Austenitic Steel Forgings
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 923 Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels
B 311 Test Method for Density Determination for Powder Metallurgy (P/M) Materials Containing Less Than Two Percent Porosity
E 112 Test Methods for Determining Average Grain Size
E 165 Test Method for Liquid Penetrant Examination
E 340 Test Method for Macroetching Metals and Alloys
E 606 Practice for Strain-Controlled Fatigue Testing
G 48 Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution

2.2 *MSS Standard:*

SP 25 Standard Marking System for Valves, Fittings, Flanges, and Unions[3]

2.3 *ASME Specifications and Boiler and Pressure Vessel Codes:*

B16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings [4]

2.4 *ASME Specification IX Welding Qualifications:*

SFA-5.4 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes[4]
SFA-5.9 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes[4]
SFA-5.11 Specification for Nickel and Nickel-Alloy Covered Welding Electrodes[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 A01.22 onSteel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] 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.

[3] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602, http://www.mss-hq.com.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

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

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *can*, *n*—the container used to encapsulate the powder during the pressure consolidation process; it is partially or fully removed from the final part.

3.1.2 *compact*, *n*—the consolidated powder from one can. It may be used to make one or more parts.

3.1.3 *consolidation*, *n*—the bonding of adjacent powder particles in a compact under pressure by heating to a temperature below the melting point of the powder.

3.1.4 *fill stem*, *n*—the part of the compact used to fill the can. It is not usually integral to the part produced.

3.1.5 *hot isostatic-pressing*, *n*—a process for simultaneously heating and forming a compact in which the powder is contained in a sealed formable enclosure usually made from metal and the so-contained powder is subjected to equal pressure from all directions at a temperature high enough to permit plastic deformation and consolidation of the powder particles to take place.

3.1.6 *lot*, *n*—a number of parts made from a single powder blend following the same manufacturing practice.

3.1.7 *part*, *n*—a single item coming from a compact, either prior to or after machining.

3.1.8 *powder blend*, *n*—a homogeneous mixture of powder from one or more heats of the same grade.

3.1.9 *rough part*, *n*—the part prior to final machining.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify in the purchase order all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (weight or number of parts),

4.1.2 Name of material or UNS number,

4.1.3 ASTM designation and year of issue,

4.1.4 Dimensions (tolerances and surface finishes should be included),

4.1.5 Microstructure examination if required (5.1.4),

4.1.6 Inspection (15.1),

4.1.7 Whether rough part or finished machined part (8.2.2),

4.1.8 Supplementary requirements, if any,

4.1.9 Additional requirements (See 7.2 and 17.1), and

4.1.10 Requirement, if any, that the manufacturer shall submit drawings for approval showing the shape of the rough part before machining and the exact location of test specimen material (See 9.3).

TABLE 1 Chemical Requirements

		Composition, %[A]										
UNS Designation	Grade	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium plus Tantalum	Tantalum	Titanium
						Martensitic Stainless Steels						
S41000	13 chromium	0.15	1.00	0.040	0.030	1.00		11.5–13.5	. . .	. . .	. . .	. . .
S41026	13 chromium 0.5 molybdenum	0.15	1.00	0.020	0.020	1.00	1.00–2.00	11.5–13.5	0.40–0.60	Other Elements Cu 0.50		
S41500	13 chromium, 4 nickel	0.05	0.50–1.00	0.030	0.030	0.60	3.5–5.5	11.5–14.0	0.50–1.00	. . .	. . .	. . .
S42390	12 chromium, 1.0 molybdenum, modified with vanadium	0.18–0.25	1.00	0.030	0.030	1.00	0.30–0.80	11.5–12.5	0.80–1.20	Other Elements N 0.03–0.08 V 0.25–0.35 Cb 0.08–0.15		
						Austenitic Stainless Steels						
S30400[B]	18 chromium, 8 nickel	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .
S30403[B]	18 chromium, 8 nickel, low carbon	0.035	2.00	0.045	0.030	1.00	8.0–13.0	18.0–20.0	. . .	. . .	. . .	. . .
S30451[C]	18 chromium, 8 nickel, modified with nitrogen	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .
S30453	18 chromium, 8 nickel, modified with nitrogen	0.030	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .
S31600[B]	18 chromium, 8 nickel, modified with molybdenum	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .
S31603[B]	18 chromium, 8 nickel, modified with molybdenum, low carbon	0.030	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .

TABLE 1 *Continued*

UNS Designation	Grade	Composition, %[A] Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium plus Tantalum	Tantalum	Titanium
S31651[C]	18 chromium, 8 nickel, modified with molybdenum and nitrogen	0.08	2.00	0.045	0.030	1.00	10.0–13.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .
S31653[C]	18 chromium, 8 nickel, modified with molybdenum and nitrogen	0.030	2.00	0.045	0.030	1.00	10.0–13.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .
S31700	19 chromium, 13 nickel 3.5 molybdenum	0.08	2.00	0.045	0.030	1.00	11.0–15.0	18.0-20.0	3.0–4.0	. . .	. . .	. . .
S31703	19 chromium, 13 nickel, 3.5 molybdenum	0.030	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .
S21904	20 chromium, 6 nickel, 9 manganese	0.04	8.0–10.0	0.045	0.030	1.00	5.5–7.5	19.0–21.5	. . .	. . .	Other Elements N 0.15–0.40	
S31254	20 chromium, 18 nickel, 6 molybdenum, low carbon	0.020	1.00	0.030	0.010	0.80	17.5–18.5	19.5–20.5	6.0–6.5	. . .	Other Elements Cu 0.50-1.00 N 0.18-0.22	
S31725	19 chromium, 15 nickel, 4 molybdenum	0.030	2.00	0.045	0.030	1.00	13.5–17.5	18.0–20.0	4.0–5.0	. . .	Other elements N 0.20	
S31726	19 chromium, 15 nickel, 4 molybdenum	0.030	2.00	0.045	0.030	1.00	14.5–17.5	17.0–20.0	4.0–5.0	. . .	Other Elements N 0.10–0.20	
N08367	22 chromium, 25 nickel, 6.5 molybdenum, low carbon	0.030	2.00	0.040	0.030	1.00	23.50–25.50	20.0–22.0	6.0–7.0		Other Elements N 0.18–0.25 Cu 0.75	
S32654	25 chromium, 22 nickel, 7 molybdenum, low carbon	0.020	2.0–4.0	0.030	0.005	0.50	21.0–23.0	24.0–25.0	7.0–8.0		Other Elements N 0.45–0.55 Cu 0.30–0.60	
					Age-Hardening Stainless Steels							
S17400	17 chromium, 4 nickel, 3 copper	0.07	1.00	0.040	0.030	1.00	3.0–5.0	15.0–17.5	. . .	0.15–0.45	Other Elements Cu 3.0–5.0	
					Austenitic-Ferritic Stainless Steels							
S31803	22 chromium, 5.5 nickel, modified with nitrogen	0.030	2.00	0.030	0.020	1.00	4.5–6.5	21.0–23.0	2.5–3.5	. . .	Other Elements N 0.08–0.20	
S32205	22 chromium, 5.5 nickel, modified with high nitrogen	0.030	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5		Other Elements Cu 0.75 N 0.14-0.20	
S32950	26 chromium, 3.5 nickel, 1.0 molybdenum	0.030	2.00	0.035	0.010	0.60	3.5–5.2	26.0–29.0	1.00–2.50	. . .	Other Elements N 0.15-0.35	
S32750	25 chromium, 7 nickel, 4 molybdenum, modified with nitrogen	0.030	1.20	0.035	0.020	0.80	6.0-8.0	24.0–26.0	3.0-5.0	. . .	Other Elements N 0.24–0.32 Cu 0.50	
S39274	25 chromium, 7 nickel, modified with nitrogen and tungsten	0.030	1.0	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.5–3.5	. . .	Other Elements N 0.24–0.32 Cu 0.20–0.80 W 1.50–2.50	
S32760[D]	25 chromium, 7 nickel, 3.5 molybdenum, modified with nitrogen and tungsten	0.030	1.00	0.030	0.010	1.00	6.0–8.0	24.0–26.0	3.0–4.0	. . .	Other Elements N 0.20–0.30 Cu 0.50–1.00 W 0.50–1.00	

TABLE 1 *Continued*

UNS Designation	Grade	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium plus Tantalum	Tantalum	Titanium
		Composition, %[A]										
S39277	25 chromium, 7 nickel, 3.7 molybdenum	0.025	0.80	0.025	0.002	0.80	6.5–8.0	24.0–26.0	3.0–4.0	. . .	Other Elements Cu 1.20–2.00 W 0.80–1.20 N 0.23–0.33	
S32505	27 chromium, 7 nickel, 3 molybdenum, modified with nitrogen and copper	0.030	1.50	0.030	0.020	1.00	4.5–7.0	24.0–27.0	2.9–3.9	. . .	Other Elements Cu 1.50–2.50 N 0.25–0.30	

[A] Maximum, unless otherwise specified.
[B] S30400, S30403, S31600, and S31603 shall have a maximum nitrogen content of 0.10 %.
[C] S30451, S31651, S30453, S31653 shall have a nitrogen content of 0.10 to 0.16 %.
[D] % Cr + 3.3 × % Mo + 16 × % N > 40 min.

5. Materials and Manufacture

5.1 *Manufacturing Practice*:

5.1.1 Compacts shall be manufactured by placing a single powder blend into a can, evacuating the can, and sealing it. The can material shall be selected to ensure that it has no deleterious effect on the final product. The entire assembly shall be heated and placed under sufficient pressure for a sufficient period of time to ensure that the final consolidated part meets the density requirements of 8.1.1.1. One or more parts shall be machined from a single compact.

5.1.2 The powder shall be prealloyed and made by a melting method capable of producing the specified chemical composition, such as but not limited to, air or vacuum induction melting, followed by gas atomization.

5.1.3 When powder from more than one heat of the same grade is used to make a blend, the heats shall be mixed thoroughly to ensure homogeneity.

5.1.4 The compact shall be sectioned and the microstructure examined to check for porosity and other internal imperfections. It shall meet the requirements of 8.1.2. The sample shall be taken from the fill stem or from a location in a part as agreed upon by the manufacturer and purchaser.

5.1.5 Unless otherwise specified in the purchase order, the manufacturer shall remove the can material from the surfaces of the consolidated compacts by chemical or mechanical methods such as by pickling or machining. This removal shall be done before or after heat treatment at the option of the manufacturer (See Note 1).

NOTE 1—Often, it is advantageous to leave the can material in place until after heat treatment or further thermal processing of the consolidated compact.

6. Chemical Composition

6.1 The steel, both as a blend and as a part, shall conform to the requirements for chemical composition prescribed in Table 1. Test Methods, Practices, and Terminology of A 751 shall apply.

6.1.1 A representative sample of each blend of powder shall be analyzed by the manufacturer to determine the percentage of elements prescribed in Table 1. The blend shall conform to the chemical composition requirements prescribed in Table 1.

6.1.2 When required by the purchaser, the chemical composition of a sample from one part from each lot of parts shall be determined by the manufacturer. The composition of the sample shall conform to the chemical requirements prescribed in Table 1.

6.2 Addition of lead, selenium, or other unspecified elements for the purpose of improving the machinability of the compact shall not be permitted.

6.3 The steel shall not contain an unspecified element other than nitrogen, for the ordered grade, to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

7. Heat Treatment

7.1 Except as provided in 7.2, the final heat treatment of all parts shall be in compliance with the requirements of Table 2. After hot isostatic-pressing and prior to final heat treatment, the compacts are permitted to be annealed, at the option of the producer, either as a part of the consolidation process or as a separate operation.

7.2 When agreed upon by the purchaser, liquid quenching may be applied to the martensitic stainless steels in place of the furnace cool or air cool specified in Table 2, provided that such quenching is followed by tempering in the temperature ranges as required in Table 2. Martensitic parts that are liquid quenched and tempered shall be marked "QT."

7.3 The final heat treatment shall be performed before or after machining at the option of the producer.

7.4 See Section S16 if a particular heat treatment method is specified by the purchaser in the purchase order.

8. Structural Integrity Requirements

8.1 *Microporosity*—The parts shall be free of microporosity as demonstrated by measurement of density as provided in 8.1.1 or by microstructural examination as provided in 8.1.2.

8.1.1 *Density Measurement*:

8.1.1.1 The density measurement shall be used for acceptance of material but not for rejection of material. The measured density for each production lot shall exceed 99 % of the density typical of that grade when wrought and in the same heat treated condition as the sample. A production lot that fails to meet this acceptance criterion is permitted to be tested at the

TABLE 2 Heat Treating Requirements

UNS No.	Heat Treat Type	Austenitizing/Solutioning Temperature °F (°C)[A]	Cooling Media	Quenching, Cool to Below °F (°C)	Tempering Temperature, min° F (°C)
		Martensitic Stainless Steels			
S41000 Class 1	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1325 [725]
	temper	not required	[B]	[B]	1325 [725]
S41000 Class 2	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1250 [675]
	temper	not required	[B]	[B]	1250 [675]
S41000 Class 3	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1100 [595]
S41000 Class 4	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1000[540]
S41026	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	400 [205]	1150 [620]
S41500	normalize and temper	1850 [1010]	air cool	200 [95]	1040-1120 [560-600]
S42390	normalize and temper	1860–1960 [1015–1070]	air cool	200 [95]	1350–1440 [730–780]
		Austenitic Stainless Steels			
S30400	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S30403	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S30451	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S30453	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31600	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31603	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31651	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31653	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31700	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31703	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S21904	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31254	solution treat and quench	2100 [1150]	liquid	500 [260]	[B]
S31725	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
S31726	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
N08367	solution treat and quench	2025 [1105]	liquid	500 [260]	[B]
S32654	solution treat and quench	2050–2160 [1120–1180]	liquid	500 [260]	[B]
		Austenitic-Ferritic Stainless Steels			
S31803	solution treat and quench	1870 [1020]	liquid	500 [260]	[B]
S32205	solution treat and quench	1870 [1020]	liquid	500 [260]	[B]
S32950	solution treat and quench	1825-1875 [995-1025][C]	liquid	500 [260]	[B]
S32750	solution treat and quench	1880 [1025]	liquid	500 [260]	[B]
S39274	solution treat and quench	1920–2060 [1050–1125]	liquid	500 [260]	[B]
S32760	solution treat and quench	2010–2085 [1100–1140]	liquid	500 [260]	[B]
S39277	solution treat and quench	1940 [1060]	liquid	175 [80]	[B]
		Age-Hardening Stainless Steels			
		Solution Heat Treatment		Aging Heat Treatment[D]	
	Condition	Temperature °F (°C)	Cool as required to below °F (°C)	Temperature °F (°C), time (h), Required Cooling	
S17400	A	1875-1975 [1025-1055]	90 [32]	. . .	
	H900	1875-1975 [1025-1055]	90 [32]	900 [480], 1.0, air cool	
	H925	1875-1975 [1025-1055]	90 [32]	925 [495], 4.0, air cool	
	H1025	1875-1975 [1025-1055]	90 [32]	1025 [550], 4.0, air cool	
	H1075	1875-1975 [1025-1055]	90 [32]	1075 [580], 4.0, air cool	
	H1100	1875-1975 [1025-1055]	90 [32]	1100 [595], 4.0, air cool	
	H1150	1875-1975 [1025-1055]	90 [32]	1150 [620], 4.0, air cool	
	H1150M	1875-1975 [1025-1055]	90 [32]	1400 [760], 2.0, air cool plus 1150 [620], 4.0, air cool	

[A] Minimum unless temperature range is listed.
[B] Not applicable.
[C] 30 min/in. of thickness.
[D] Unless otherwise noted, it is permitted to vary the aging treatment temperature to obtain the required properties. The listed times are minimum time at temperature and the treatment is permitted to be extended to obtain the required ductility. Material treated at an intermediate temperature must meet the ductility requirements of the next higher hardening or aging temperature, or both.

option of the producer, for microporosity in accordance with the microstructural examination as provided in 8.1.2.

8.1.1.2 Density shall be determined for one sample from each production lot by measuring the difference in mass of the sample when weighed in air and when weighed in water and multiplying this difference by the density of water (Archimede's principle). The equipment used shall be capable of determining density within ± 0.004 lb/in.^{3}(0.10 g/cm^3). Alternatively, at the option of the producer, it is permitted to use Test Method B 311 to determine the density.

8.1.1.3 At the option of the producer, the density shall be compared to the room temperature density typical of wrought steels of the same class of grades, 0.28 lb/in.^{3} (7.8 g/cm^3) for age-hardening, martensitic, and austenitic-ferritic grades, and 0.29 lb/in.^{3} (8.0 g/cm^3) for austenitic grades, or to the density of a wrought reference sample of the same grade heat treated in accordance with the requirements of Table 2 (See Note 2).

NOTE 2—The actual density of stainless steel varies slightly with composition and heat treatment. For this reason, small differences in the measured density from the typical density for a class of grades may be the result of differences in alloy content, heat treatment, or microporosity. When density values are measured that are less than the density typical of a class of grades, it is appropriate to examine the sample for microporosity by the more specific metallographic examination procedures.

8.1.2 *Microstructural Examination*:

8.1.2.1 The microstructure when examined at 20-50×, 100-200×, and 1000-2000× shall be reasonably uniform and shall be free of voids, laps, cracks, and porosity.

8.1.2.2 One sample from each production lot shall be examined. The sample, at the option of the producer, shall be taken after hot-isostatic pressing or after final heat treatment. The microstructure shall meet the requirements of 8.1.2.1.

8.1.2.3 If the sample fails to meet the requirements for acceptance, each part in the lot is permitted to be retested, at the option of the producer, and those that pass shall be accepted.

8.2 *Hydrostatic Tests*—After they have been machined, pressure-containing parts shall be tested to the hydrostatic shell test pressures prescribed in ASME B16.5 for the applicable steel rating for which the part is designed and shall show no leaks. Parts ordered under these specifications for working pressures other than those listed in the ASME B16.5 ratings shall be tested to such pressures as may be agreed upon between the manufacturer and purchaser.

8.2.1 No hydrostatic test is required for weld neck or other flanges.

8.2.2 The compact manufacturer is not required to perform pressure tests on rough parts that are to be finish machined by others. The fabricator of the finished part is not required to pressure test parts that are designed to be pressure containing only after assembly by welding into a larger structure. The manufacturer of the compacts, however, shall be responsible, as required in 16.1 for the satisfactory performance of the parts under the final test required in 8.2.

8.3 *Ultrasonic Tests*—When specified in the order, austenitic-ferritic stainless steel parts made from S32505 shall be ultrasonic tested according to the procedures described in Section S7.

9. Mechanical Properties

9.1 The material shall conform to the requirements for mechanical properties prescribed in Table 3 at room temperature.

9.2 Mechanical test specimens shall be obtained from production parts or from the fill stems. Mechanical test specimens shall be taken from material that has received the same heat treatment as the parts that they represent. If repair welding is required (See Section 15), the test specimens prior to testing shall accompany the repaired parts if a post weld treatment is done.

9.3 For normalized and tempered parts, or quenched and tempered parts, the central axis of the test specimen shall correspond to the ¼ *T* plane or deeper position, where *T* is the maximum heat treated thickness of the represented part. In addition, for quenched and tempered parts, the midlength of the test specimen shall be at least *T* from any second heat treated surface. When the section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location, as agreed to by the purchaser and the supplier.

9.4 For all annealed stainless steels, the test specimen may be taken from any convenient location.

9.5 *Tension Tests*:

9.5.1 *Age-Hardening and Martensitic Stainless Steels*—One tension test shall be made for each production lot in each heat treatment charge. When the heat treating cycles are the same and the furnaces (either batch or continuous type) are controlled within ±25 °F (±14 °C) and equipped with recording pyrometers so that complete records of heat treatment are available, then only one tension test from each production lot of each type of part (See Note 3) and section size is required instead of one test from each production lot in each heat-treatment charge.

NOTE 3—"Type" in this case is used to describe the shape of the part such as a flange, elbow, tee, and so forth.

9.5.2 *Austenitic and Austenitic-Ferritic Stainless Steels*—One tension test shall be made for each production lot. The tension test specimen shall be made from material accompanying the parts in final heat treatment.

9.5.3 Testing shall be performed in accordance with Test Methods and Definitions A 370 using the largest feasible of the round specimens. The gage length for measuring elongation shall be four times the diameter of the test section.

9.6 *Hardness Tests*:

9.6.1 When two or more parts are produced, a minimum of two pieces per batch or continuous run as defined in 9.6.2 shall be hardness tested in accordance with Test Methods and Definitions A 370 to ensure that the parts are within the hardness limits given for each grade in Table 3. When only one part is produced, it shall be hardness tested as required. The purchaser is permitted to verify that the requirement has been met by testing at any location on any part provided such testing does not render the part useless.

9.6.2 When the reduced number of tension tests permitted by 9.5.1 is applied, additional hardness tests shall be made on parts or samples as defined in 9.2 distributed throughout the charge. At least eight samples shall be checked from each batch load and a least one check/h shall be made from a continuous run. When the furnace charge is less than eight parts, each part shall be checked. If any hardness test result falls outside the prescribed limits, the entire lot of parts shall be reheat treated and the requirements of 9.5.1 shall apply.

9.7 *Fatigue Tests*—When specified in the order, the fatigue strength of austenitic stainless steel components intended for service above 1000 °F (540 °C) shall be determined in accordance with Section S18.

TABLE 3 Tensile and Hardness Requirements

UNS Designation	Tensile Strength, min, ksi (MPa)	Yield Strength, min, ksi (MPa)[A]	Elongation in 2 in. (50 mm) or 4*D*, min, %	Reduction of Area, min, %	Brinell Hardness Number
Martensitic Stainless Steels					
S41000 Class 1	70 (485)	40 (275)	18	35.0	143–187
S41000 Class 2	85 (585)	55 (380)	18	35.0	167–229
S41000 Class 3	110 (760)	85 (585)	15	35.0	235–302
S41000 Class 4	130 (895)	110 (760)	12	35.0	263–321
S41026	110-135 (760–930)	90 (620)	16	45.0	235–285
S41500	115 (790)	90 (620)	15	45.0	295 max
S42390	100–125 (690–862)	75 (517)	14.0	. . .	. . .
Austenitic Stainless Steels					
S30400	75 (515)[B]	30 (205)	30	50	. . .
S30403	70 (485)[C]	25 (170)	30	50	. . .
S30451	80 (550)	35 (240)	30	50	. . .
S30453	75 (515)[B]	30 (205)	30	50	. . .
S31600	75 (515)[B]	30 (205)	30	50	. . .
S31603	70 (485)[C]	25 (170)	30	50	. . .
S31651	80 (550)	35 (240)	30	50	. . .
S31653	75 (515)[B]	30 (205)	30	50	. . .
S31700	75 (515)[B]	30 (205)	30	50	. . .
S31703	70 (485)[C]	25 (170)	30	50	. . .
S21904	90 (620)	50 (345)	45	60	. . .
S31254	94 (650)	44 (300)	35	50	. . .
S31725	75 (525)	30 (205)	40.0	50.0	. . .
S31726	80 (550)	35 (240)	40.0	50.0	. . .
N08367	95 (655)	45 (310)	30.0	50.0	
S32654	109 (750)	62 (430)	40.0	. . .	250 max
Age-Hardening Stainless Steels					
UNS Designation, condition					
S17400, A	. . .	. . .	. . .	. . .	363 max
S17400, H900	190 (1310)	170 (1170)	6	15	388 min
S17400, H925	170 (1170)	155 (1070)	7	20	375 min
S17400, H1025	155 (1070)	145 (1000)	8	27	331 min
S17400, H1075	145 (1000)	125 (860)	9	28	311 min
S17400, H1100	140 (965)	115 (795)	10	29	302 min
S17400, H1150	135 (930)	105 (725)	11	30	277 min
S17400, H1150M	115 (795)	75 (520)	14	35	255 min
Austenitic-Ferritic Stainless Steels					
S31803	90 (620)	65 (450)	25	45	. . .
S32205	95 (655)	65 (450)	25.0	. . .	293 max
S32950	100 (690)	70 (485)	15	. . .	. . .
S32750	116 (800)	80 (550)	15	. . .	310 max
S39274	116 (800)	80 (550)	15	30	310 max
S32760	109–130 (750–895)	80 (550)	25.0	45	. . .
S39277	118 (820)	85 (585)	25.0	50	. . .
S32505	116 (800)	80 (550)	25	50	240–270

[A] Determined by the 0.2 % offset method.
[B] For sections over 5 in. (130 mm) in thickness, the minimum tensile strength shall be 70 ksi (485 MPa).
[C] For sections over 5 in. (130 mm) in thickness, the minimum tensile strength shall be 65 ksi (450 MPa).

10. Corrosion Testing

10.1 Corrosion testing is not required by this specification.

10.2 Austenitic stainless steels shall be capable of meeting the intergranular corrosion test requirements described in Section S11.

10.3 When required by the purchaser, the stainless steels shall be tested in the final heat treated condition for pitting or crevice corrosion resistance according to the procedures described in Section S12.

10.4 Austenitic-ferritic stainless steels shall be capable of meeting the test requirements described in Section S13.

11. Product Analysis

11.1 The purchaser is permitted to make a product analysis on parts supplied to this specification. Samples for analysis shall be taken from midway between the center and surface of solid parts, midway between the inner and outer surfaces of hollow parts, midway between the center and surface of

TABLE 4 Product Analysis Tolerances for Stainless Steels[A]

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	0.030, incl	0.005
	over 0.030 to 0.20 incl	0.01
Manganese	to 1.00, incl	0.03
	over 1.00 to 3.00, incl	0.04
	over 3.00 to 6.00	0.05
	over 6.00 to 10.00	0.06
Phosphorus	to 0.040, incl	0.005
Sulfur	to 0.030, incl	0.005
Silicon	to 1.00, incl	0.05
	over 1.00 to 5.00, incl	0.10
Chromium	over 10.00 to 15.00, incl	0.15
	over 15.00 to 20.00, incl	0.20
	over 20.00 to 27.50, incl	0.25
Nickel	to 1.00, incl	0.03
	over 1.00 to 5.00, incl	0.07
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 20.00, incl	0.15
	over 20.00 to 22.00, incl	0.20
Molybdenum	to 0.20 incl	0.01
	over 0.20 to 0.60, incl	0.03
	over 0.60 to 2.00, incl	0.05
	over 2.00 to 7.00, incl	0.10
Titanium	all ranges	0.05
Columbium+tantalum	all ranges	0.05
Tantalum	to 0.10, incl	0.02
Cobalt	0.05 to 0.20, incl	0.01[B]
Nitrogen	to 0.19 incl	0.01
	over 0.19 to 0.25	0.02
	over 0.25 to 0.35	0.03
	over 0.35 to 0.45	0.04
	over 0.45 to 0.60	0.05
Columbium	0.05 to 0.20, incl	0.01
Aluminum	to 0.05 incl	0.01
Vanadium	to 0.10 incl	0.01
	over 0.10 to 0.25 incl	0.02
Cerium	0.03 to 0.08	-0.005 +0.01
Tungsten	to 1.00, incl	0.04
Copper	to 0.50, incl	0.03
	Over 0.50 to 1.00, incl	0.05
	Over 1.00 to 3.00, incl	0.10
	Over 3.00 to 5.00, incl	0.15

[A] This table does not apply to heat analysis.
[B] Product analysis limits for cobalt under 0.05 % have not been established and the producer should be consulted for those limits.

full-size prolongations, or from broken mechanical test specimens. The chemical composition thus determined shall conform to Table 1 with the tolerances as stated in Table 4.

12. Reheat Treatment

12.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer is permitted to reheat treat the parts and repeat the tests specified in Section 9, but not more than twice.

13. Workmanship, Finish and Appearance

13.1 The parts shall be free of scale, machining burrs, and other injurious imperfections as defined herein. The parts shall have a workmanlike finish and machined surfaces (other than surfaces having special requirements) shall have a surface finish not to exceed 250 AA (arithmetic average) roughness height.

13.2 At the discretion of the purchaser, finished parts shall be subject to rejection if surface imperfections acceptable under 13.4 are not scattered but appear over a large area in excess of what is considered to be a workmanlike finish.

13.3 *Depth of Imperfections*—Linear imperfections shall be explored for depth. When the depth encroaches on the minimum wall thickness of the finished parts, such imperfections shall be considered defects.

13.4 *Machining or Grinding Imperfections Not Classified as Defects*—Surface imperfections not classified as defects shall be treated as follows:

13.4.1 Seams, laps, tears, or slivers not deeper than 5 % of the nominal wall thickness or 1⁄16 in. (1.6 mm), whichever is less, need not be removed. If these imperfections are removed, they shall be removed by machining or grinding.

13.4.2 Mechanical marks or abrasions and pits shall be acceptable without grinding or machining, provided their depth does not exceed the limitations set forth in 13.4.1. Imperfections that are deeper than 1⁄16 in. (1.6 mm), but which do not encroach on the minimum wall thickness of the part, shall be removed by grinding to sound metal.

13.4.3 When imperfections have been removed by grinding or machining, the outside dimension at the point of grinding or machining may be reduced by the amount removed. Should it be impracticable to secure a direct measurement, the wall thickness at the point of grinding or at an imperfection not required to be removed, shall be determined by deducting the amount removed by grinding from the nominal finished wall thickness of the part, and the remainder shall not be less than the minimum specified or required wall thickness.

14. Repair by Welding

14.1 Weld repairs shall be permitted (See Section S8) only with prior approval of the purchaser and with the following limitations and requirements:

14.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

14.1.2 The weld metal shall be deposited using the electrodes specified in Table 5 except as otherwise provided in Section S14. The electrodes shall be purchased in accordance with ASME Specifications SFA-5.4, SFA-5.9, or SFA-5.11. The submerged arc process with neutral flux, the gas metal-arc welding and gas tungsten-arc welding processes are permitted to be used.

14.1.3 Defects shall be removed completely prior to welding by chipping or grinding to sound metal as verified by magnetic particle inspection in accordance with Test Method A 275/A 275M for the age-hardening, martensitic, or austenitic-ferritic stainless steels, or by liquid penetrant inspection in accordance with Test Method E 165 for all grades.

14.1.4 After repair welding, the welded area shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic-particle or liquid-penetrant inspection, as applicable.

TABLE 5 Repair Welding Requirements

UNS Designation	Electrodes[A]	Preheat and Interpass Temperature Range, °F (°C)	Minimum Post-Weld Heat Treatment Temperature °F (°C)
		Age-Hardening Stainless Steels	
S17400	17 Cr, 4 Ni, 3 Cu	NR[B]	1875-1925 (1025-1055), air cool, plus 900-1150 (480-620)
		Martensitic Stainless Steels	
S41000 Class 1	E 410-15 or 16	400-700 (205-370)	1250 (675)
S41000 Class 2	E 410-15 or 16	400-700 (205-370)	1250 (675)
S41026	13 % Cr, 1½ % Ni, ½ % Mo	400-700 (205-370)	1150 (620)
S41500	13 % Cr, 4 % Ni	300-700 (150-370)	1050 (565)
S42390		400-750 (205-400)	1350-1440 (730-780)
		Austenitic Stainless Steels	
S30400	E 308-15 or 16	NR[B]	1900 (1040) + WQ[C]
S30403	E 308L-15 or 16	NR	1900 (1040) + WQ
S30451	E 308-15 or 16	NR	1900 (1040) + WQ
S30453	E 308L-15 or 16	NR	1900 (1040) + WQ
S31600	E 316-15 or 16	NR	1900 (1040) + WQ
S31603	E 316L-15 or 16	NR	1900 (1040) + WQ
S31651	E 316-15 or 16	NR	1900 (1040) + WQ
S31653	E 316L-15 or 16	NR	1900 (1040) + WQ
S31700	E 317-15 or 16	NR	1900 (1040) + WQ
S31703	E 317L-15 or 16	NR	1900 (1040) + WQ
S21904	XM-10W	NR	NR
S31254	E NiCrMo-3	NR	2100 (1150) + WQ
S31725	[D]	. . .	2100 (1150) + WQ
S31726	[D]	. . .	2100 (1150) + WQ
N08367	E NiCrMo-3	NR	2025 (1105) + WQ
S32654	25 % Cr, 61 % Ni, 14 % Mo	NR	2100 (1150) + WQ
		Austenitic-Ferritic Stainless Steels	
S31803	22 % Cr, 5.5 % Ni, 3 % Mo	NR	NR
S322205	22 % Cr, 5.5 % Ni, 3 % Mo	NR	NR
S32950	26 % Cr, 8 % Ni, 2 % Mo	NR	NR
S32750	25 % Cr, 7 %, Ni, 4 % Mo	NR	NR
S39274	25 % Cr, 7 % Ni, 3 % Mo, W	NR	NR
S32760	25 % Cr, 7 % Ni, 3.5 Mo	NR	NR
S39277	25 % Cr, 7 % Ni, 3 % Mo, 1.5 % Cu, 1 % W	NR	NR
S32505	27 % Cr, 7 % Ni, 3 % Mo, 2 % Cu	NR	NR

[A] Electrodes shall comply with ASME SFA-5.4, and corresponding ER grades of SFA-5.9 or SFA-5.11.
[B] NR = not required.
[C] WQ = water quench.
[D] Match filler metal is available. Fabricators also have used AWS A5.14, Class ER, NiCrMo-3 and AWS A5.11, Class E, NiCrMo-3 filter metals.

14.1.5 The preheat, interpass temperature, and post-weld heat treatment requirements given in Table 5 shall be met.

14.1.6 Repair by welding shall not exceed 10 % of the surface area of the part. Repair by welding shall not exceed 33⅓ % of the wall thickness of the finished part or ⅜ in. (9.5 mm), whichever is less.

14.1.7 No weld repairs are permitted for S41000 Classes 3 and 4.

15. Inspection

15.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy the inspector that the material is being furnished in accordance with the purchase order. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture unless otherwise agreed upon.

16. Rejection

16.1 Each part that develops defects during shop working operations or in service shall be rejected and the manufacturer notified.

16.2 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon between the manufacturer and the purchaser.

17. Certification

17.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. When specified in the purchase order or contract, a report of the test results shall be furnished.

18. Product Marking

18.1 Identification marks consisting of the manufacturer's symbol or name (See Note 4), the heat or blend number, designation of service rating, the specification number, the designation showing the grade of material, and the size shall be stamped or marked legibly on each part or the parts shall be marked in accordance with Standard SP 25 and in such position so as not to injure the usefulness of the part. The specification number marked on the part need not include specification year of issue and revision letter.

NOTE 4—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

18.1.1 Quenched and tempered martensitic stainless steel parts shall be marked with the letters QT following the specification designation.

18.1.2 Hot isostatically-pressed parts repaired by welding shall be marked with the letter "W" following the specification designation.

18.1.3 When test reports are required, the markings shall consist of the manufacturer's symbol or name, the grade symbol, and such other markings as necessary to identify the part with the test report (18.1.1 and 18.1.2 shall apply).

18.1.4 Hot isostatically-pressed parts meeting all requirements for more than one class or grade are permitted, at the option of the producer, to be marked with more than one class or grade designation, such as S30400/S30409, S30400/S30403, etc.

18.2 *Bar Coding*—In addition to the requirements in 18.1, bar coding is acceptable as a supplemental identification method. The purchaser is permitted to specify in the order that a specific bar coding system be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

19. Keywords

19.1 age-hardening stainless steel; austenitic stainless steels; austenitic-ferritic stainless steel; gas-atomized powder; hot isostatically-pressed stainless steel parts; martensitic stainless steel; pipe fittings, steel; piping applications; pressure containing parts; stainless steel fittings; stainless steel flanges; steel valves; temperature service applications, elevated; temperature service applications, high

SUPPLEMENTARY REQUIREMENTS

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

S1. Macroetch Test

S1.1 A sample part shall be sectioned and etched to show internal imperfections. The test shall be conducted according to Test Method E 340. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S2. Product Analysis

S2.1 A product analysis in accordance with Section 11 shall be made from one randomly selected part representing each size and type (See Note 3) of part on the order. If the analysis fails to comply, each part in that lot, at the option of the manufacturer, shall be checked and accepted if the analysis for the part complies with the requirements, or the lot shall be rejected. All results shall be reported to the purchaser.

S3. Tension Tests

S3.1 In addition to the requirements of Section 9, one tension specimen shall be obtained from a representative part from each production lot at a location agreed upon between the manufacturer and the purchaser. The results of the test shall comply with Table 3 and shall be reported to the purchaser.

S4. Magnetic Particle Examination

S4.1 All accessible surfaces of a finished martensitic, age hardening, or austenitic-ferritic stainless steel part, shall be examined by a magnetic-particle method. The method shall be in accordance with Test Method A 275/A 275M. Acceptance limits shall be agreed upon between the manufacturer and purchaser.

S5. Liquid Penetrant Examination

S5.1 All accessible surfaces shall be examined by a liquid penetrant method in accordance with Test Method E 165. Acceptance limits shall be agreed upon between the manufacturer and the purchaser.

S6. Hydrostatic Testing

S6.1 A hydrostatic test at a pressure agreed upon between the manufacturer and the purchaser shall be applied by the manufacturer.

S7. Ultrasonic Testing

S7.1 Austenitic-Ferritic stainless steel parts made of S32505 shall be 100 % ultrasonic tested with straight and angle beam probes in accordance with Practice A 745/A 745M. Acceptance limits shall be agreed upon between the manufacturer and the purchaser.

S8. Repair Welding

S8.1 No repair welding shall be permitted without prior approval of the purchaser. If permitted, the restrictions of Section 14 shall apply.

S9. Heat Treatment Details

S9.1 The manufacturer shall furnish a detailed test report containing the information required in 17.1 and shall include all pertinent details of the heat treating cycle given the parts.

S10. Material for Optimum Resistance to Stress-Corrosion Cracking

S10.1 Austenitic stainless steel parts shall be furnished in the solution-annealed condition as a final operation with no subsequent cold working permitted unless specifically permitted by the purchaser.

S11. Intergranular Corrosion Tests

S11.1 Intergranular corrosion tests shall be performed on specimens of austenitic stainless steel in accordance with Practices A 262.

S11.2 For the austenitic stainless steels, details concerning the number of specimens and their source and location are to be a matter of agreement between the manufacturer and the purchaser.

S12. Pitting and Crevice Corrosion Test

S12.1 The stainless steels in the final heat treated condition shall be tested in accordance with Test Method G 48. Test procedures and acceptance criteria shall be a matter of agreement between the manufacturer and purchaser.

S13. Detrimental Intermetallic Phase Test

S13.1 The austenitic-ferritic stainless steels shall be tested in accordance with the test methods given in Test Methods A 923. Acceptance criteria, if not specified in Test Methods A 923, shall be a matter of agreement between the manufacturer and the purchaser.

S14. Special Filler Metal

S14.1 In repair welded S31600, S31603, S31609, and S31651 parts, the deposited weld metal shall conform to E 308 composition wire. Parts repair welded with E 308 weld metal shall be marked S___W308.

S15. Hardness Test

S15.1 Each part shall be hardness tested and shall meet the requirements of Table 3.

S16. Heat Treatment of Austenitic Stainless Parts

S16.1 The purchaser shall specify the heat treatment method in 7.1 that shall be employed.

S16.2 The manufacturer shall provide a test report containing the information required in 17.1 and shall include a statement of the heat treatment method employed.

S17. Grain Size for Austenitic Stainless Steels

S17.1 Hot isostatically-pressed parts made from austenitic stainless steel grades other than H grades shall be tested for average grain size by Test Methods E 112. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S18. Fatigue Acceptance Test

S18.1 For austenitic stainless steel components intended for service above 1000 °F (540 °C), a uniaxial fatigue test shall be performed.

S18.2 The fatigue test shall be performed in air at 1100 °F (595 °C) at an axial strain range of 1.0 % with a one hour hold period at the maximum positive strain point in each cycle. Test specimen location and orientation shall be in accordance with the general guidance of Test Methods and Definitions A 370 and the applicable product specifications. Testing shall be conducted in accord with Practice E 606. The test shall exceed 200 cycles without fracture or a 20 % drop in the load range.

S18.3 Failure to meet this requirement shall be cause for rejection of all parts from that blend.

S18.4 Test frequency shall be the same as for tension tests (See 9.5). Retesting is permitted. For a retest, two additional specimens produced from the same blend shall be tested and both specimens must pass the cyclic life requirement. Further retests are not permitted.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 988/A 988M – 05, that may impact the use of this specification. (Approved September 1, 2007)

(*1*) Revised UNS Sxxxxx to S32505 in 8.3, S7.1, Table 1, Table 3, and Table 5.

(*2*) Deleted UNS S30600 from Table 3.

Designation: A 984/A 984M – 03

Standard Specification for Steel Line Pipe, Black, Plain-End, Electric-Resistance-Welded[1]

This standard is issued under the fixed designation A 984/A 984M; 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 covers electric-resistance-welded, black, plain-end, steel pipe for use in the conveyance of fluids under pressure. Pipe in sizes NPS 1 to 26, inclusive, with nominal wall thickness 0.750 in. [19.1 mm] or less, as given in ASME B36.10M is included. Pipe having other dimensions, in this size range, may be furnished provided such pipe complies with all other requirements of this specification.

1.2 It is intended that the pipe be capable of being circumferentially welded in the field when welding procedures in accordance with the requirements of the applicable pipeline construction code are used.

1.3 The values stated in either inch-pound units or in SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values in each system are not exact equivalents; therefore, each system is to be used independently of the other.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy and Austenitic Alloy Steel Tubes

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

2.2 *API Standard:*

API RP 5L3 Recommended Practice for Conducting Drop-Weight Tear Tests on Line Pipe[3]

2.3 *ASME Standard:*

ASME B36.10M Welded and Seamless Wrought Steel Pipe[4]

3. Terminology

3.1 *Definitions*—For terminology used in this specification, refer to Terminology A 941.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *electric-resistance welding, n*—electric-resistance welding is a process of forming a longitudinal seam wherein the edges are pressed together mechanically after the heat for welding has been generated by the resistance to the flow of electric current.

3.2.2 *lot, n*—a quantity of pipe of the same ordered diameter, heat, wall thickness, and grade, as given in Table 1.

3.2.3 *specified outside diameter (OD), n*—the outside diameter specified in the purchase order or the outside diameter listed in ASME B36.10M for the nominal pipe size specified in the purchase order.

4. General Requirements

4.1 Pipe furnished under this specification shall conform to the applicable requirements of Specification A 530/A 530M unless otherwise provided herein.

5. Ordering Information

5.1 It is the purchaser's responsibility to specify in the purchase order all information necessary to purchase the needed material. Examples of such information include, but are not limited to, the following:

5.1.1 Specification designation and year of issue,

5.1.2 Quantity (feet or metres),

5.1.3 Grade (standard or intermediate, see Table 2 and 8.1.6),

5.1.4 Size (either nominal (NPS) or outside diameter and wall thickness),

5.1.5 Length (see 12.4),

5.1.6 End finish (plain-end beveled or special, see 13.1),

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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 A01.09 on Carbon Steel Tubular Products.

Current edition approved September 10, 2003. Published October 2003. Originally approved in 1998. Last previous edition approved in 2002 as A 984 – 02.

[2] 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.

[3] Available from The American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

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

TABLE 1 Lot Size and Sample Size for Mechanical and Impact Testing

Size Designation	Lot Size	Sample Size
<NPS 2	50 tons [45 Mg] or fraction thereof	1
NPS 2 through NPS 5	400 lengths	1
NPS 6 through NPS 12	200 lengths	1
>NPS 12	100 lengths	1

TABLE 2 Tensile Requirements

Grade	Yield Strength, Min		Yield Strength,[A] Max		Tensile Strength, Min	
	psi	MPa	psi	MPa	psi	MPa
35	35 000	240	65 000	450	60 000	415
50	50 000	345	77 000	530	70 000	485
60	60 000	415	80 000	550	75 000	515
70	70 000	485	87 000	600	80 000	550
80	80 000	550	97 000	670	90 000	620

[A] See 8.1.1.

5.1.7 End use of the pipe,
5.1.8 Special requirements,
5.1.9 Supplementary requirements, and
5.1.10 Bar coding (see 16.3).

6. Manufacture

6.1 Pipe shall be manufactured by the electric-resistance-welding process. The entire pipe shall be normalized or the weld seam and its heat-affected zones shall receive a continuous in-line heat treatment above the Ac_3 temperature. Complete penetration and coverage of the weld seam and its heat-affected zones by such heat treatment shall be confirmed by metallographic examination of weld area cross-section specimens, taken at least once per eight hours per operating shift, but more frequently if diameter or wall thickness changes are made.

6.2 The internal and external flash resulting from the welding process shall be removed (see 14.1 and 14.2).

7. Chemical Composition

7.1 The steel for any grade, by heat and product analyses, shall contain no more than 0.22 % carbon, 0.015 % sulfur, and 0.025 % phosphorus.

7.2 The steel shall contain no more than 0.0007 % boron, by heat analysis.

7.3 The carbon equivalent (CE) shall not exceed 0.40 %, calculated from the product analysis using the following equation:

$$CE = C + F\left[\frac{Mn}{6} + \frac{Si}{24} + \frac{Cu}{15} + \frac{Ni}{20} + \frac{(Cr + Mo + V + Cb)}{5}\right] \quad (1)$$

where:

F is a compliance factor that is dependent upon the carbon content, as given below:

Carbon Content, %	*F*	*Carbon Content, %*	*F*
< 0.06	0.53	0.15	0.88
0.06	0.54	0.16	0.92
0.07	0.56	0.17	0.94
0.08	0.58	0.18	0.96
0.09	0.62	0.19	0.97
0.10	0.66	0.20	0.98
0.11	0.70	0.21	0.99
0.12	0.75	0.22	1.00
0.13	0.80		
0.14	0.85		

7.4 Product analyses shall be made on at least two samples from each heat of steel.

7.5 All analyses shall be in accordance with Test Methods, Practices, and Terminology A 751, and shall include all elements required in the carbon equivalent equation of 7.3, in addition to titanium, phosphorus, sulfur, and boron, except that product analysis for boron is not required.

7.6 If one or both of the product analyses representing a heat fails to conform to the specified requirements, the heat shall be rejected, or analyses shall be made on double the original number of test samples that failed, each of which shall conform to the specified requirements.

8. Mechanical Properties

8.1 *Tension Test*:

8.1.1 The material shall conform to the tensile requirements given in Table 2 and in 8.1.6. The yield strength maxima apply only to pipe NPS 8 and larger.

8.1.2 The yield strength corresponding to a total extension under load of 0.5 % of the gage length shall be determined.

8.1.3 A test specimen taken across the weld shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe required. Neither yield strength nor elongation determinations are required for transverse weld specimens. This test is not required for pipe smaller than NPS 8.

8.1.4 Transverse tension tests shall be performed on pipe NPS 8 and larger and the test specimens shall be taken opposite the weld. All transverse test specimens shall be approximately 1½ in. [38 mm] wide in the gage length and each shall represent the full wall thickness of the pipe from which the test specimen was cut.

8.1.5 Longitudinal tension tests shall be performed on pipe smaller than NPS 8. Longitudinal test specimens shall be either full-size test specimens or strip test specimens, at the option of the manufacturer. Strip test specimens shall be from a location approximately 90° from the weld.

8.1.6 Grades intermediate to those given in Table 2 may be furnished. For intermediate grades, the difference between the specified maximum yield strength and the specified minimum yield strength and the difference between the specified minimum tensile strength and the specified minimum yield strength shall be as given in Table 2 for the next higher listed grade. For each grade, the minimum elongation in 2 in. [50 mm] shall be calculated using the following equation:

$$e = C\frac{A^{0.2}}{U^{0.9}} \quad (2)$$

where:

e = minimum elongation in percent, rounded to the nearest percent,
C = constant = 625 000 [1940],

A = cross-sectional area of the tensile test specimen in in.^{2} [mm^2], based upon the specified outside diameter or the nominal specimen width and the specified wall thickness, rounded to the nearest 0.01 in.^{2} [1 mm^2]. If the area thus calculated is greater than 0.75 in.^{2} [485 mm^2], the value of 0.75 in.^{2} [485 mm^2] shall be used.
U = specified minimum tensile strength, psi [MPa].

8.2 *Impact Test*:

8.2.1 Except as allowed by 8.2.2, all sizes of pipe shall be Charpy V-notch tested in accordance with Test Methods and Definitions A 370. For pipe smaller than NPS 5, such tests shall be longitudinal, taken 90° from the weld. For pipe NPS 5 and larger, such tests shall be transverse, taken 90° from the weld.

8.2.2 The basic specimen is full size Charpy V-notch. Where full size specimens, either conventional or containing the original OD surface, cannot be obtained due to a combination of diameter and wall thickness, two-thirds size, half-size, or one-third size specimens shall be used. Where combinations of diameter and wall thickness do not permit the smallest specimen size, there is no requirement for impact testing. In all cases, the largest possible specimen size shall be used, except where such a specimen size will result in absorbed energy values greater than 80 % of the testing machine capacity.

8.2.3 Where subsize specimens are used, the requirements for absorbed energy shall be the adjusted values obtained by the following relationships, with the calculated values rounded to the nearest foot pound-force [joule]:

$$\text{For } \frac{2}{3} \text{ size: } N = R \times 0.67 \tag{3}$$

$$\text{For } \frac{1}{2} \text{ size: } N = R \times 0.50 \tag{4}$$

$$\text{For } \frac{1}{3} \text{ size: } N = R \times 0.33 \tag{5}$$

where:
N = adjusted value, ft·lbf [J], and
R = value required by 8.2.4.

8.2.4 For pipe smaller than NPS 5, the absorbed energy requirement for full size specimens shall be 15 ft·lbf [20 J]. For pipe NPS 5 through NPS 26, the absorbed energy requirement for full size specimens shall be the value calculated using the following equation, rounded to the nearest foot pound-force, or 15 ft·lbf [20 J] , whichever is the greater.

$$V\ (\text{full size}) = Cx\sqrt{D}xS^{1.5} \tag{6}$$

where:
V = minimum average value required for full size specimens, ft·lbf [J],
C = constant = 0.024 [0.00036],
D = specified outside diameter, in. [mm], and
S = 0.72 × specified minimum yield strength, ksi [MPa].

8.2.5 The factor of 0.72 in 8.2.4 may be increased by agreement between the purchaser and the manufacturer.

8.2.6 Charpy impact testing shall be performed at 32°F [0°C], unless a lower temperature is agreed upon between the purchaser and the manufacturer.

8.2.7 Each Charpy impact test shall exhibit at least 75 % shear area average for the three specimens.

8.3 *Flattening Test*:

8.3.1 The weld ductility shall be determined by tests on two full-section specimens of at least 2 in. [50 mm] long. Such specimens shall be flattened cold between parallel plates. The weld shall be placed at 90° and at 0° from the direction of applied force (point of maximum bending). Except as allowed by 8.3.2, no cracks or breaks exceeding ⅛ in. [3 mm] in any direction in the weld or in the parent metal shall occur on the outside surface of the specimen before the distance between the plates is less than the value of H calculated using the following equation:

$$H = \frac{3.05t}{(0.05 + 3\ t/D)} \tag{7}$$

where:
H = distance between flattening plates, in. [mm],
t = specified wall thickness, in. [mm], and
D = specified outside diameter, in. [mm].

8.3.2 Cracks that originate at the edge of the specimen and are less than ¼ in. [6 mm] in any direction shall not be cause for rejection.

9. Hydrostatic Test

9.1 Each length of pipe shall be subjected to the hydrostatic test without leakage through the weld seam or the pipe body.

9.2 Each length of pipe NPS 2 or larger shall be tested, by the manufacturer, to a minimum hydrostatic pressure calculated from the following equation:

$$\text{Inch–Pound Units: } P = 2\left(\frac{St}{D}\right) \times C \tag{8}$$

$$\text{SI Units: } P = 2000\frac{St}{D} \times C \tag{9}$$

where:
P = minimum hydrostatic test pressure, psi [kPa],
S = specified minimum yield strength, psi [MPa],
t = specified wall thickness, in. [mm],
D = specified outside diameter, in. [mm], and
C = 0.60 for pipe NPS 2 through NPS 5,
0.75 for pipe larger than NPS 5 through NPS 8,
0.85 for pipe larger than NPS 8 through NPS 18,
0.90 for pipe larger than NPS 18.

9.3 For pipe sizes smaller than NPS 2, the test pressures given in Table 3 are arbitrary. For pipe in sizes smaller than NPS 2 with wall thicknesses lighter than those listed, the test pressure for the next heavier listed specified wall thickness shall be used. For intermediate specified outside diameters for pipe sizes smaller than NPS 2, the test pressures given for the next smaller specified outside diameter shall be used.

9.4 Where computed test pressures are not an exact multiple of 10 psi [100 kPa], they shall be rounded to the nearest 10 psi [100 kPa].

9.5 The minimum hydrostatic test pressure required to satisfy these requirements need not exceed 3000 psi [20 700 kPa]. This does not prohibit testing at a higher pressure at the manufacturer's option. The hydrostatic test pressure shall be maintained for not less than 5 s for all pipe sizes.

TABLE 3 Hydrostatic Test Pressure

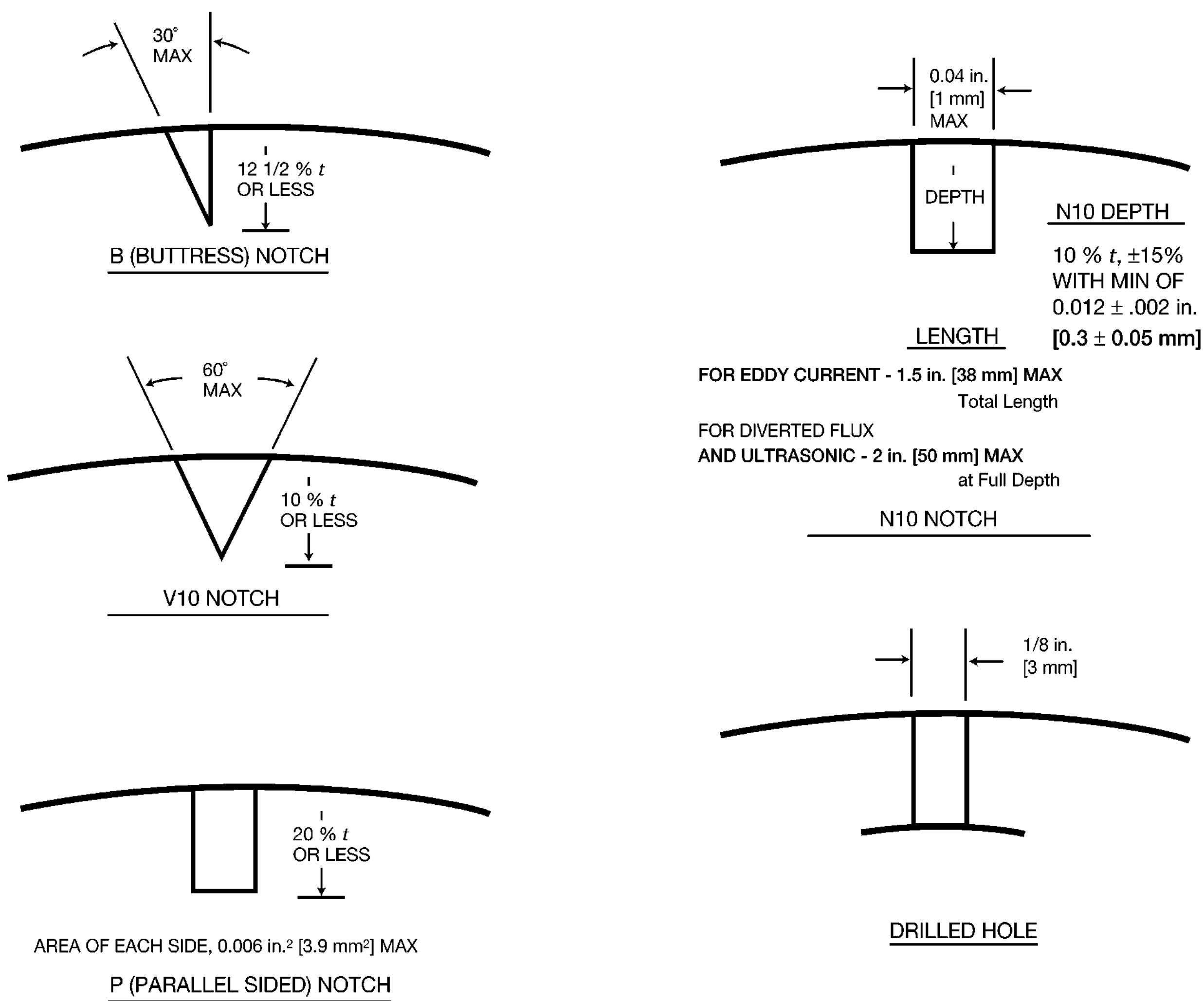
NPS Designator	OD, in. [mm]	Wall Thickness, in. [mm]	Test Pressure, Min, psi [kPa]
1	1.315 [33.4]	0.133 [3.4]	700 [4800]
		0.179 [4.6]	850 [5900]
		0.250 [6.4]	950 [6600]
		0.358 [9.1]	1000 [6900]
1¼	1.660 [42.2]	0.140 [3.6]	1300 [9000]
		0.191 [4.9]	1900 [13 100]
		0.250 [6.4]	2000 [13 800]
		0.382 [9.7]	2300 [15 900]
1½	1.900 [48.3]	0.145 [3.7]	1300 [9000]
		0.200 [5.1]	1900 [13 100]
		0.281 [7.1]	2000 [13 800]
		0.400 [10.2]	2300 [15 900]

10. Nondestructive Electric Test

10.1 The weld seam of each length of pipe NPS 2 or larger shall be inspected using a nondestructive electric test as follows:

10.2 *Ultrasonic and Electromagnetic Inspection*—Any equipment utilizing the ultrasonic or electromagnetic principles and capable of continuous and uninterrupted inspection of the weld seam shall be used. The equipment shall be checked with an applicable reference standard as described in 10.3 at least once every 8 h of inspection to demonstrate the effectiveness of the inspection procedures. The equipment shall be adjusted to produce well-defined indications when the reference standard is scanned by the inspection unit in a manner simulating the inspection of the product. The location of the equipment shall be at the manufacturer's option.

10.3 *Reference Standards*—Reference standards shall have both the outside diameter and the wall thickness within the tolerances specified for the production pipe to be inspected, and may be of any convenient length as determined by the pipe manufacturer. Reference standards shall be either full sections or coupons taken from the pipe. Reference standards shall contain machined notches as shown in Fig. 1, one on the inside surface and one on the outside surface, or a drilled hole as shown in Fig. 1, at the option of the pipe manufacturer. The notches shall be parallel to the weld seam, and shall be separated by a distance sufficient to produce two separate and distinguishable signals. The ⅛-in. [3-mm] drilled hole shall be drilled through the wall and perpendicular to the surface of the



NOTE 1—t = specified wall thickness

FIG. 1 Calibration Standards

reference standard as shown in Fig. 1. Care should be taken in the preparation of the standard to ensure freedom from fins or other edge roughness, or distortion of the standard.

NOTE 1—The calibration standards shown in Fig. 1 are convenient standards for the calibration of nondestructive testing equipment. The dimensions of such standards should not be construed as the minimum size imperfection detectable by such equipment.

10.4 *Acceptance Limits*—Table 4 gives the height of acceptance limit signals in percent of the height of signals produced by the calibration standards. Imperfections in the weld seam that produce a signal greater than the acceptance limit given in Table 4 shall be considered defects.

10.5 Surface condition, operator qualification, extent of examination, and standardization procedure shall be in accordance with the provisions of Specification A 450/A 450M.

11. Number of Tests

11.1 For pipe produced from coils, the flattening test in Section 10 shall be performed on pipe from each end of the coil length. In the event of a weld stop, the test shall be performed on each pipe end adjacent to the weld stop. For pipe produced in single lengths, the test shall be performed on each end of each length.

11.2 Tension and impact testing shall be performed on a lot basis, with the lot size and sample sizes as given in Table 1.

12. Dimensions, Mass, and Permissible Variations

12.1 The dimensions and masses per unit length of some of the pipe sizes included in this specification are given in ASME B36.10M. The mass per unit length of pipe having an intermediate specified outside diameter or intermediate specified wall thickness, or both, shall be calculated using the appropriate equation in 12.2.

12.2 *Mass*—The mass of a single length of pipe shall not vary more than +10 %, -3.5 % from its theoretical mass, as calculated using its mass per unit length and its measured length. Pipe masses per unit length not listed in ASME B36.10M shall be calculated using the following equation:

$$\text{Inch–Pound Units: } M = t\,(D - t) \times 10.69 \tag{10}$$

$$\text{SI Units: } M = t\,(D - t) \times 0.024\,66 \tag{11}$$

where:
M = mass per unit length, lb/ft [kg/m],
t = specified wall thickness, in. [mm], and
D = specified outside diameter, in. [mm].

The mass of any order item shall be not more than 1.75 % under its theoretical mass.

12.3 *Wall Thickness*— The wall thickness at any point shall be not more than 8 % under the specified wall thickness.

TABLE 4 Acceptance Limits

Type of Notch	Size of Hole, in. [mm]	Acceptance Limit Signal, %
N10, V10	⅛ [3]	100
B, P		80

12.4 *Length*—Unless otherwise agreed upon between the purchaser and the manufacturer, pipe shall be furnished in the nominal lengths and within the tolerances given in Table 5, as specified.

12.5 *Outside Diameter*—Pipe sizes NPS 20 and smaller shall permit the passage over the ends, for a distance of 4 in. [100 mm], of a ring gage that has a bore diameter no larger than the specified outside diameter plus the diameter plus tolerance. Outside diameter measurements of pipe larger than NPS 20 shall be made with a diameter tape. Outside diameter measurements, away from the ends, of pipe NPS 20 and smaller, shall be made with a snap gage, caliper, or other device that measures actual outside diameter in a single plane.

13. End Finish

13.1 Pipe furnished to this specification shall be plain-end beveled with ends beveled to an angle of 30°, +5°, -0°, measured from a line drawn perpendicular to the axis of the pipe, and with a root face of 1⁄16 in. ± 1⁄32 in. [1.5 mm, +1.0, –0.5 mm], or shall have another plain-end configuration, as specified in the purchase order.

14. Workmanship, Finish, and Appearance

14.1 The depth of groove resulting from the removal of the internal flash shall not be greater than that given in Table 6 for the various wall thicknesses. Depth of groove is defined as the difference between the wall thickness measured approximately 1 in. [25 mm] from the weld line and the wall thickness measured at the groove.

14.2 The external flash shall not extend above the surface of the pipe by more than 0.010 in. [0.2 mm].

14.3 Surface imperfections that penetrate more than 8 % of the specified wall thickness or encroach on the minimum permissible wall thickness shall be considered defects. Pipe with defects shall be given one of the following dispositions:

14.3.1 The defect shall be removed by grinding, provided that a smooth curved surface remains and the remaining wall thickness is within specified limits.

NOTE 2—It is acceptable for the outside diameter at the point of grinding to be reduced by the amount so removed.

14.3.2 The section of the pipe containing the defect shall be cut off within the requirements for length.

14.3.3 The length shall be rejected.

14.4 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In case of a dispute, the measurement determined by the use of a mechanical caliper shall govern.

TABLE 5 Tolerances on Length

Nominal Length		Minimum Length		Minimum Average Length for Each Order Item		Maximum Length	
ft	m	ft	m	ft	m	ft	m
20	6	9.0	2.74	17.5	5.33	22.5	6.86
40	12	14.0	4.27	35.0	10.67	45.0	13.72
50	15	17.5	5.33	43.8	13.35	55.0	16.76
60	18	21.0	6.40	52.5	16.00	65.0	19.81
80	24	28.0	8.53	70.0	21.34	85.0	25.91

TABLE 6 Depth of Groove Tolerance

Specified Wall Thickness (*t*)	Maximum Depth of Groove
0.150 in. [3.8 mm] or less	0.10*t*
0.151 in. [3.8 mm] to 0.301 in. [7.6 mm], excl	0.015 in. [0.4 mm]
0.301 in. [7.6 mm] or greater	0.05*t*

14.5 Repairs of the weld seam or the pipe body, by welding, are not permitted.

14.6 Pipe smaller than NPS 4 shall be reasonably straight. All other pipe shall be randomly checked for straightness, and deviation from a straight line shall not exceed 0.2 % of the length.

14.7 The pipe shall contain no dents greater than 10 % of the specified outside diameter or ¼ in. [6 mm], whichever is the lesser, measured as the gap between the lowest point of the dent and a prolongation of the original contour of the pipe. Cold-formed dents deeper than ⅛ in. [3 mm] shall be free of sharp bottom gouges. The gouges may be removed by grinding provided the remaining wall thickness is within specified limits. The length of the dent in any direction shall not exceed one half the pipe's specified outside diameter.

15. Certification

15.1 Where specified in the purchase order or contact, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met. Where specified in the purchase order or contact, a report of the test results shall be furnished.

16. Product Marking

16.1 Except as allowed by 16.2, each length of pipe shall be legibly marked to show the specification number, the name or brand of the manufacturer, ERW, the grade, the specified wall thickness, the specified outside diameter, the heat number or heat code, and the length. The length shall be marked in feet and tenths of a foot, or metres to two decimal places, whichever is applicable.

16.2 For bundled pipe NPS 1½ or smaller, it shall be permissible for the required markings to be included on a tag that is fastened securely to each bundle.

16.3 In addition to the requirements of 16.1 and 16.2, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order that a specific bar coding system be used.

17. Keywords

17.1 black steel pipe; electric-resistance-welded; line pipe

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified in the purchase order.

S1. **Drop-Weight Tear Testing**

S1.1 The drop-weight tear test shall be conducted in accordance with API RP 5L3.

S1.2 The temperature selected for conducting the drop-weight tear test and the criteria for acceptance shall be as specified in the purchase order.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 984/A 984M-02, that may impact the use of this specification. (Approved September 10, 2003)

(*1*) Revised Table 2.

Standard Specification for Fusion Bonded Epoxy-Coated Pipe Piles[1]

This standard is issued under the fixed designation A 972/A 972M; 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 covers pipe piles with protective fusion-bonded epoxy powder coating applied by the electrostatic spray, flocking, or fluidized bed process.

NOTE 1—The coating applicator is identified throughout this specification as the manufacturer.

1.2 Other organic coatings may be used provided they meet the requirements of this specification.

1.3 Requirements for the powder coating are contained in Annex A1.

1.4 This specification is applicable for orders in either SI units (as Specification A 972M) or inch-pound units [as Specification A 972]. The values stated in either SI or inch-pound units are to be regarded as standard. Within the text, the inch-pound units are shown in brackets.

1.5 The following precautionary statement refers to the test method portion only, Section 8, of this standard: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 252 Specification for Welded and Seamless Steel Pipe Piles

B 117 Practice for Operating Salt Spray (Fog) Apparatus

D 4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser

G 8 Test Method for Cathodic Disbonding of Pipeline Coatings

G 12 Test Method for Nondestructive Measurement of Film Thickness of Pipeline Coatings on Steel

G 14 Test Method for Impact Resistance of Pipeline Coatings (Falling Weight Test)

G 20 Test Method for Chemical Resistance of Pipeline Coatings

2.2 *American Petroleum Institute Specification:*

API RP 5L7 Recommended Practice for Internal Fusion-Bonded Epoxy Coating of Line Pipe[3]

2.3 *National Association of Corrosion Engineers Standards:*

TM0175 Visual Standard for Surfaces of New Steel Centrifugally Blast Cleaned with Steel Shot or Steel Grit (NACE No. 2)[4]

RP0490 Holiday Detection of Fusion-Bonded Epoxy External Pipeline Coatings of 250 to 750 µm (10 to 30 mils)[4]

2.4 *Steel Structures Painting Council Standards:*

SSPC VIS 1 Visual Standards[5]

SSPC-SP1 Surface Preparation Specification No. 1: Solvent Cleaning[5]

SSPC-SP10 Near White Blast Cleaning[5]

3. Ordering Information

3.1 Orders for pipe piles under this specification may include the following information:

3.1.1 Specification for designation and year of issue,

3.1.2 Size (pipe pile outside diameter and nominal wall thickness),

3.1.3 Quantity.

3.1.4 Length,

3.1.5 Portions to be coated (full length or distance from end),

3.1.6 Requirements for certifications (see 4.1 and 12.1),

3.1.7 Requirements for material samples (see 4.3),

3.1.8 Requirements for patching material (see 4.4),

3.1.9 Requirements for visual standards for surface cleaning comparison (see 5.1),

3.1.10 Requirements for test frequency (see 8.1, 8.2), and

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is under the direct responsibility of Subcommittee A01.09 on Carbon Steel Tubular Products .

Current edition approved Sept 1, 2004. Published October 2004. Originally approved in 1997. Last previous edition approved in 2000 as A 972/A 972M – 00.

[2] 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.

[3] Available from the American Petroleum Institute (API), 1220 L St., Washington DC 20005.

[4] Available from the National Association of Corrosion Engineers (NACE), 1440 South Creek, Houston, TX 77084.

[5] Available from Society for Protective Coatings (SSPC), 40 24th St., 6th Floor, Pittsburgh, PA 15222-4656.

3.1.11 Requirements for inspections at the manufacturing plant (see 10.1).

4. Materials and Manufacture

4.1 Steel pipe piles to be coated shall meet the requirements of Specification A 252 as ordered.

NOTE 2—Surface conditions such as slivers, gouges, laminations, pits, and sharp edges may cause coating application difficulties and effort should be made to hold these conditions to a minimum.

4.2 The powder coating shall meet the requirements listed in Annex A1 and shall be approved by the purchaser.

4.2.1 If specified in the order, a written certification shall be furnished to the purchaser that properly identifies the supplied powder coating, batch designation of each batch used in the order, quantity represented, date of manufacture, name and address of manufacturer, and states that the powder coating, meets the requirements of Annex A1.

4.3 If specified in the order, a representative 0.2 kg [8 oz.] sample from each batch of the powder coating shall be supplied to the purchaser. The sample shall be packaged in an airtight container and identified by batch designation.

4.4 Patching material shall be compatible with the powder coating and recommended by the manufacturer of the powder coating. If specified in the order, patching material shall be supplied to the purchaser.

5. Surface Preparation

5.1 Prior to blast cleaning, the surfaces of steel pipe piles to be coated shall be precleaned, as required, in accordance with SSPC-SP1. Steel surfaces shall be cleaned by abrasive blast cleaning to near-white metal in accordance with SSPC-SP10. The cleaning media used shall produce an anchor pattern profile of 38–100 µm [1.5–4.0 mils]. Either of the following visual standards of comparison shall be used to define the final surface condition: SSPC-VIS 1 or NACE TM0175. Expended blasting media debris and dust shall be removed from blasted surfaces prior to applying the powder coating.

5.2 Prior to application of the fusion-bonded epoxy powder coating, raised slivers, scabs, laps, sharp edges, or seams shall be removed using abrasive grinders. No individual area of grinding shall exceed 230 cm^2 [36 $in.^2$]. The total area of grinding shall not exceed 1 % of the total surface area.

NOTE 3—Pipe piles with excessive grinding should be reblasted prior to coating to establish a suitable anchor pattern in the ground area.

6. Coating Application

6.1 The powder coating shall be applied to the cleaned steel surfaces before visible oxidation occurs, but not exceeding 3 h after cleaning.

6.2 To achieve the required coating thickness (see 7.1), the steel shall be preheated prior to applying the powder coating in accordance with the powder coating manufacturer's written recommendations. The heat source shall not leave a residue or contaminant on the steel surfaces. If oxidation occurs, the steel shall be cooled to ambient temperature and recleaned before applying the powder coating.

6.3 The powder coating shall be applied and cured in accordance with the powder coating manufacturer's written recommendations.

6.4 Areas of pipe piles not requiring coating to allow for welding or other purposes shall be specified by the purchaser and shall be blocked-out during the coating application.

7. Requirements for Coated Pipe Piles

7.1 *Coating Thickness*:

7.1.1 The minimum coating thickness after curing on the pipe piles shall be 300 µm [12 mils].

7.1.2 The coating thickness shall be measured in accordance with Test Method G 12 following the instructions for calibration and use recommended by the thickness gage manufacturer.

7.2 *Coating Continuity*:

7.2.1 Holiday detection shall be performed on each coated pipe pile in accordance with NACE RP0490 or a 67.5 V direct current, 80-k Ω wet-sponge holiday detector in conjunction with a wetting agent.

7.2.2 Holidays detected shall be patched in accordance with the patching material manufacturer's written recommendations.

8. Test Frequency

8.1 Measure the coating thickness on a minimum of every 10^{th} pipe pile.

8.2 Test the coating continuity over the entire coated surface of each pipe pile.

9. Permissible Coating Damage and Repair of Damaged Coating

9.1 Coating damage to pipe piles due to handling or other causes shall be repaired in the manufacturer's plant with patching material prior to shipment.

9.2 The areas of coating damage shall be prepared for the application of patching material by cleaning the damaged area, removing the damaged coating using grinders or other suitable means, feathering the adjacent coating, and removing all remaining residue or dust.

9.3 The application of the patching materials to the damaged areas shall be in accordance with the patching material manufacturer's written recommendation.

10. Inspection

10.1 The purchaser's representative (inspector) shall be allowed entry to the area of the manufacturer's plant where work on the purchaser's order is being performed during times of operation. The manufacturer shall afford the inspector all reasonable facilities to satisfy that the material is being furnished in accordance with this specification.

10.2 The inspector shall be allowed to select completed pipe piles randomly for inspection and testing in the manufacturer's plant. Such inspections and tests conducted by the inspector shall not interfere unnecessarily with the manufacturer's operation.

11. Rejection

11.1 Coated pipe piles represented by test specimens that do not meet the requirements of this specification shall be rejected. At the manufacturer's option, rejected sections shall be replaced, or may be stripped of coating, cleaned, recoated, and resubmitted for acceptance testing in accordance with the requirements of this specification.

12. Certification

12.1 Upon request by the purchaser, the manufacturer shall furnish, at the time of shipment, written certification that the coated sections meet the requirements of this specification.

13. Handling, Packaging and Shipping

13.1 Coated pipe piles shall not be dropped, dragged, or handled in any manner that will result in damage to the coating. Equipment for handling coated sections shall have padded contact areas.

13.2 Pipe piles shall be stored off the ground on supports that prevent excessive deflection. Stacked pipe piles shall be isolated with suitable separators to prevent coating damage.

13.3 Bundling bands for packaging and tie-down bands for shipping shall be padded or made of material that shall not damage the coating. Pipe piles shall be supported during shipping in a manner that prevents impact damage to the coating and excessive deflection.

14. Keywords

14.1 corrosion resistance; fusion-bonded epoxy powder coating; pipe piles

ANNEX

(Mandatory Information)

A1. QUALIFICATION OF ORGANIC COATINGS FOR PIPE PILING

A1.1 Scope

A1.1.1 This specification covers qualification requirements for a barrier epoxy powder coating for protecting pipe piling.

A1.2 Coating Material

A1.2.1 The coating material shall be a 100 % solids, heat curable, thermosetting, epoxy powder coating.

A1.2.2 At the request of the purchaser, the manufacturer of the fusion-bonded epoxy powder coating shall be required to certify that products used to coat pipe piling meet the requirements of this specification.

A1.3 Coating Requirements

A1.3.1 *Chemical Resistance*—The chemical resistance of the coating shall be evaluated according to Test Method G 20 by immersing coated plates in each of the following: distilled water, an aqueous solution of 3 *M* $CaCl_2$, an aqueous solution of 3 *M* NaOH, and a solution saturated with $Ca(OH)_2$. Specimens without holidays and specimens with intentional holes drilled through the coating 6 mm [¼ in.] in diameter shall be tested. The temperature of the test solutions shall be 24 ± 2°C [75 ± 4°F]. The minimum test time shall be 45 days. The coating shall not blister, soften, lose bond, or develop holidays during this period. The coating surrounding the intentionally made holes shall exhibit no undercutting during the 45-day period.

A1.3.2 *Impact Resistance*—The impact resistance of the coating shall be tested in accordance with Test Method G 14 using a 16 mm [⅝ in.] diameter tup, 300 µm [12 mils] minimum coating thickness on a 3 mm [⅛ in.] thick panel at 24 ± 2°C [75 ± 4°F]. Three tests shall be performed. The minimum acceptable value shall be 9 J [80 in.-lb.] of impact with no visible breaks in the coating.

A1.3.3 *Coating Flexibility*—The flexibility of the coating shall be evaluated by bending three 16 mm [⅝ in.] thick panels coated with a minimum of 0.3 mm [12 mils] of coating over a mandrel at 0 ± 2°C [32 ± 4°F]. Tests shall be performed in accordance with 5.3.3.1 of API RP 5L7 with an acceptance criterion of 1.5° total deflection at 0 ± 2°C [32 ± 40°F]. Bends shall be visually inspected; any visible tears or cracks in the coating at bends is cause for rejection, unless located with 2.5 mm [0.1 in.] of the edge of the strap. Unopened stretch marks on the coating surface do not constitute coating failure.

A1.3.4 *Abrasion Resistance*—The abrasion resistance of the coating shall be tested by a taber abraser (see Test Method D 4060), or its equivalent, using four standard steel plates for this apparatus coated to a thickness of 0.30 to 0.35 mm [12 to 14 mils] and CS-10 wheels with a 1-kg [2.2-lb] load per wheel. The maximum allowable weight loss shall not exceed 100 mg [0.0035 oz.]/1000 cycles. The abrasion wheels shall be cleaned after 500 cycles.

A1.3.5 *Salt Fog*—The weathering resistance of the coating shall be tested using a salt spray cabinet following Practice B 117 for 1000 h. The coating shall not blister, and the coating disbondment shall not exceed 3 mm [0.12 in], as measured from the edge of the scribe area.

A1.3.6 *Cathodic Disbondment*—The effects of electrical and electrochemical stresses on the bond of the coating to steel and on the film integrity shall be assessed in an elevated cathodic disbondment test. Test Method G 8 shall be followed except that flat plates coated with the proposed material shall be used. The drilled coating defect shall be 3 mm [0.12 in.] in diameter, the electrolyte solution shall be 3 % NaCl by mass dissolved in distilled water, the electrolyte solution temperature shall be 65 ± 2°C [150 ± 3.6°F], and the test duration shall be 24 hours. The average coating disbondment radius of three test panels shall not exceed 6 mm [0.24 in.] as measured from the edge of the intentional coating defect.

Designation: A 962/A 962M – 07a

Standard Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range[1]

This standard is issued under the fixed designation A 962/A 962M; 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 covers a group of common requirements that shall apply to carbon, alloy and stainless steel fasteners or fastener materials, or both, under any of the following ASTM Specifications (or under any other ASTM Specifications that invoke this specification or portions thereof):

Title of Specifications	ASTM Designation
Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service	A 193/A 193M
Carbon and Alloy Steel Nuts for Bolts for High Pressure and High-Temperature Service	A 194/A 194M
Alloy Steel Bolting Materials for Low-Temperature Service	A 320/A 320M
Alloy-Steel Turbine-Type Bolting Material Specially Heat Treated for High-Temperature Service	A 437/A 437M
High-Temperature Bolting Materials With Expansion Coefficients Comparable to Austenitic Stainless Steels	A 453/A 453M
Alloy-Steel Bolting Materials for Special Applications	A 540/A 540M
Precipitation-Hardening Bolting Material (UNS N07718) for High Temperature Service	A 1014/A 1014M

1.2 In case of conflict the requirements of the individual product specification shall prevail over those of this specification.

1.3 Additional requirements may be specified by mutual agreement between the purchaser and supplier.

1.4 Values stated in either inch-pound or SI units (metric) are to be regarded separately. The SI units are shown in brackets within the text and tables. The values stated in each system are not exact equivalents, therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units shall apply unless the "M" designation of the product specification is specified in the order.

2. Referenced Documents

The following documents shall form a part of this specification to the extent specified. The latest issue shall apply unless otherwise specified.

2.1 *ASTM Standards:* [2]

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for

A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications

A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

A 320/A 320M Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 437/A 437M Specification for Alloy-Steel Turbine-Type Bolting Material Specially Heat Treated for High-Temperature Service

A 453/A 453M Specification for High-Temperature Bolting Materials, with Expansion Coefficients Comparable to Austenitic Stainless Steels

A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings

A 540/A 540M Specification for Alloy-Steel Bolting Materials for Special Applications

A 574 Specification for Alloy Steel Socket-Head Cap Screws

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 788/A 788M Specification for Steel Forgings, General Requirements

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] 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.

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

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A 1014/A 1014M Specification for Precipitation-Hardening Bolting Material (UNS N07718) for High Temperature Service
E 3 Guide for Preparation of Metallographic Specimens
E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
E 384 Test Method for Microindentation Hardness of Materials
E 1417 Practice for Liquid Penetrant Testing
E 1444 Practice for Magnetic Particle Testing
E 1916 Guide for Identification and/or Segregation of Mixed Lots of Metals
F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series

2.2 *ANSI Standards:*
B1.1 Screw Threads[3]
B1.13M Metric Screw Threads – M Profile[3]
B1.2 Gages and Gaging for Unified Screw Threads[3]
B1.3M Screw Thread Gaging Systems for Dimensional Acceptability of Metric Screw Threads[3]
B18.2.1 Square and Hex Bolts and Screws[3]
B18.2.3.6M Metric Heavy Bolts
B18.3 Hexagon Socket and Spline Socket Screws[3]

2.3 *Other Documents:*
ASNT Recommended Practice No. SNT-TC-1A [4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *bar*—a solid rolled or forged section that is long in relationship to its cross-sectional dimensions with a relatively constant cross section throughout its length. See Specification A 29/A 29M for definitions relating to the production of hot wrought and cold finished bars.

3.1.2 *bolting material*—rolled or forged bars or blanks, wire, rod, threaded bar, rotary pierced or extruded seamless tubes, bored bars, or forged hollows from forged or rolled bar segments to be manufactured into bolts, screws, studs, washers, and nuts.

3.1.3 *certifying organization*—the company or association responsible for the conformance and marking of the product to the specification requirements.

3.1.4 *class*—a term used to differentiate between different heat treatment conditions or strength levels, or both, often within the same grade but sometimes within the same family of materials. May also apply to work hardened condition or strength level, or both.

3.1.5 *grade*—an alloy described individually and identified by its own designation in a table of chemical requirements within any specification.

3.1.6 *killed steel*—steel deoxidized, by addition of strong deoxidizing agents or by vacuum treatment, to reduce the oxygen content to such a level that no reaction occurs between carbon and oxygen during solidification.

3.1.7 *length, fasteners subject to full size testing*—that portion of the fastener whose body diameter is approximately the same as the nominal thread size.

3.1.8 *lot*—unless otherwise specified, a lot shall consist of:

3.1.8.1 *bolting material, heat treated in batch type furnaces*—all material of the same heat or cast of material, condition, finish, and size subjected to the same heat treatment in one tempering charge and submitted for inspection at the same time.

3.1.8.2 *bolting material, heat treated in continuous type furnaces*—all material of the same heat or cast of material, condition, finish, and size heat treated without interruption in a continuous type furnace during an eight hour period.

3.1.8.3 *bolting material, non heat treated (strain hardened)*—all material of the same heat or cast of material, condition, reduction (cold work), finish and size.

3.1.8.4 *fasteners, machined from bolting material*—all fasteners machined from the same lot of material defined as outlined in either 3.1.8.1 or 3.1.8.2, above without any subsequent heat treatment or hot or cold forming.

3.1.8.5 *fasteners, heat treated in batch type furnaces*—all items produced by any technique (forming, machining, etc.) from the same heat or cast of material, of the same prior condition, the same size, and subjected to the same heat treatment in one tempering charge.

3.1.8.6 *fasteners, heat treated in continuous type furnaces*—all items produced by any technique (forming, machining, etc.) from the same heat or cast of material, of the same prior condition, of the same size, subjected to the same heat treatment in a four hour period and in one tempering charge.

3.1.8.7 *fasteners, non heat treated (strain hardened)*—all fasteners of the same heat or cast of material, condition, reduction (cold work), finish and size.

3.1.8.8 *strain hardened material*—austenitic stainless steel material which has been subjected to cold working sufficient to cause a significant increase in strength.

3.2 *Definitions*—For definitions of other terms used in this specification, refer to Terminology A 941.

4. Ordering Information

4.1 It is the purchaser's responsibility to specify in the purchase order all information necessary to purchase the needed material. Examples of such information include, but are not limited, to the following:

4.1.1 Quantity and size,

4.1.2 Product specification number with grade, class, type, as applicable, and including the product specification year date,

4.1.3 Any additional information required by the individual product specification,

4.1.4 Supplementary requirements,

4.1.5 Additional requirements (see 5.2, 5.4, 5.5, 6.1, 7.4, 13.1, 13.3.1, 13.3.3, 13.5.2, 13.6, 15.8, and 19.1).

4.1.6 Additional ordering options provided in the individual product specification, and

4.1.7 Dimensions (diameter, length of point, overall length, finish, shape, threads, etc.).

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

5. Melting Process

5.1 Unless otherwise specified in the individual product specification, the steel shall be fully killed. Use of the basic oxygen process shall be limited to grades containing less than 6 % chromium.

5.2 If a specific type of melting is required by the purchaser, it shall be stated on the purchase order.

5.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting such as electroslag remelting or vacuum remelting. If secondary melting is employed, the heat shall be defined as all of the ingot remelted from a single primary heat.

5.4 Steel may be cast in ingots or may be continuously cast. When steel of different grades is continuously cast identification of the resultant transition material is required. The steel producer shall remove the transition material by an established procedure that positively separates the grades. Should the purchaser deem it necessary to have the transition zone of two heats of the same grade which are continuously cast discarded, the purchaser shall invoke Supplementary Requirement S53.

5.5 *Quality*—The steel producer quality control procedures shall provide sufficient testing of carbon and alloy steels in accordance with Method E 381 or other suitable method as agreed upon between the purchaser and the producer to assure the internal quality of the product.

5.5.1 *Ingot Cast Product*—Visual examination of transverse sections shall show no imperfections worse than the macrographs of Method E 381 S2-R2-C3 or equivalent as agreed upon.

5.5.2 *Strand Cast Product*—Visual examination of traverse sections in accordance with Method E 381 shall reveal none of the conditions shown in macrographs 1-5, 7,12-18 of Plate III. Conditions 6, 8-11 shall not be present to a degree greater than the macrographs of Plates I and II, S2-R2-C3.

6. Materials and Manufacture

6.1 Bars shall be produced in accordance with Specifications A 29/A 29M or A 484/A 484M as applicable. Finish (hot or cold, ground, rough turned, drawn, etc.) shall be at the option of the manufacturer unless otherwise specified.

6.2 Fasteners shall be produced in accordance with the product specification.

7. Chemical Composition

7.1 *Chemical Analysis*—Heat or product chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

7.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of those elements specified in the individual product specification. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical analysis thus determined shall conform to the requirements of the individual product specification. Product analysis (check analysis) tolerances shall not be applied to heat analysis requirements.

7.3 *Product Analysis*—When performed, by manufacturer, purchaser, end user, and so forth, samples for analysis shall be taken from midway between center and surface of solid parts, midway between inner and outer surfaces of hollow parts, midway between center and surface of full-size prolongations or from broken mechanical test specimens. The chemical composition thus determined shall conform to the limits of the product specification, within the permissible tolerances found in Tables 5 and 6 of Specification A 29/A 29M and Table 1 of Specification A 484/A 484M as appropriate for the grade being supplied. When multiple samples are taken from the same lot for product analysis individual elements shall not vary both above and below the specified range.

7.4 For continuous cast materials the requirements of 8.2 or 8.3, as appropriate, of Specification A 788/A 788M shall be met.

7.5 Steels with intentional additions of lead, bismuth, or tellurium shall not be supplied or used. Steels with intentional additions of selenium may only be supplied or used when specifically called out in the product specification.

7.6 The starting material shall not contain any unspecified elements, other than nitrogen in austenitic stainless steels, for the ordered grade(s) to the extent that it then conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

8. Mechanical Properties

8.1 *Method of Mechanical Tests*—All tests shall be conducted in accordance with Test Methods and Definitions A 370 unless otherwise specified.

8.2 For the purpose of determining conformance to the product specification requirements, specimens shall be obtained from the production material, or, in the case of forgings, from separately forged test blanks prepared from the stock used to make the finished product. Heat treatment shall be completed prior to removal of material for mechanical testing.

8.3 If separately forged test blanks are used, they shall be of the same heat of steel, be subjected to substantially the same reduction and working as the production forging they represent, be heat treated in the same furnace charge and under the same conditions as the production forging, and be of the same nominal thickness as the maximum heat treated thickness of the production forging.

8.4 *Bars*—Tension and impact tests representing bar stock shall be taken in accordance with the requirements of Annex A1 of Test Methods and Definitions A 370. Impact tests are not required on bars ½ in. and under in diameter.

8.5 *Fasteners, Machined from Heat Treated Bar*—Mechanical properties of fasteners machined from heat treated bar shall be represented by the tests run on the bar in accordance with 8.4.

8.6 *Fasteners, All Classes—Produced by other methods*—When fasteners have been produced by forming, when they have been subjected to heat treatment, or when the nominal thread size falls into a different diameter range than that of the starting bar as shown in the applicable specifications, then tests shall be run on material taken from those fasteners.

8.6.1 Tension test specimens taken from finished fasteners shall be machined to the form and dimensions and from the positions shown in Annex A3 of Test Methods and Definitions

A 370. Impact tests are not required on material from externally threaded fasteners when the thread diameter is ½ in. and under.

9. Hardness Requirements

9.1 The material shall conform to the hardness requirements prescribed in the product specification. Hardness testing shall be performed in accordance with Test Methods and Definitions A 370.

9.2 Tensile tests prevail over hardness tests in the event a conflict exists relative to minimum strength unless otherwise specified in the product specification.

10. Tensile Requirements

10.1 *Bars and Specimens Machined From Fasteners*—The material shall conform to the tensile property requirements prescribed in the product specification.

10.1.1 When the dimensions of the material to be tested will permit, the tension test specimens shall be machined to the form and dimensions of the standard 2–in. [50–mm] gage length tension test specimen described in Test Methods and Definitions A 370.

10.1.2 When the dimensions of the material to be tested do not permit full size samples, small size specimens meeting the requirements of Test Methods and Definitions A 370 shall be used.

11. Proof Load and Cone Proof Requirements

11.1 *Proof Load Test*—Nuts shall be assembled on a threaded mandrel or a test bolt as illustrated in Fig. 1(a) Tension Method or (b) Compression Method. The minimum proof load required by the product specification shall be applied using a free running cross head speed of 1.0 in [25 mm] per minute maximum and shall be held for at least 10 s. The nut shall resist this load without stripping or rupture, and shall be removable by hand, without use of tooling, after the load is released. A wrench may be used to loosen the nut one-half turn maximum to start it in motion. The test shall be discarded if the threads of the mandrel or test bolt are damaged during the test.

11.1.1 Mandrels shall have a hardness of 45 HRC minimum with threads of the appropriate series and conforming to the requirements of ANSI B1.1 Class 3A or ANSI B1.13M tolerance 4H except that the maximum major diameter shall be the minimum major diameter plus 0.25 times the major diameter tolerance.

11.1.2 The test bolt shall have threads appropriate to the standard specified for the nut being tested and shall have a yield strength in excess of the specified proof load of the nut being tested.

11.1.3 The mandrel/tension method shall be used when arbitration is required.

11.2 *Cone Proof Load Test*—This test is performed when visible surface discontinuities become a matter of issue. The test uses a conical washer and threaded mandrel to determine the load-carrying ability of hardened steel nuts through 1½ in. [36 mm] in diameter assembled as shown in Fig. 2. The minimum cone proof load required by the product specification shall be applied using a free running cross head speed of 0.12 in. [3 mm] per minute maximum and shall be held for at least 10 s. The nut shall support its specified cone proof load without stripping or rupture.

11.2.1 Mandrels shall conform to the requirements of 11.1.1.

11.2.2 Conical washers shall have a hardness of 57 HRC minimum and a hole diameter equivalent to the nominal diameter of the mandrel +0.002, -0.000 in. [+0.05 and -0.00 mm].

11.2.3 The contact point of the cone shall be sharp for nut sizes ½ in. [12 mm] or less. For sizes over ½ in.[12 mm] , the point shall be flat and 0.015 ± 0.001 in. [0.38 + 0.03 mm] in width.

11.2.4 Cone proof loads may be determined as shown in Tables 1 and 2 when they are not specified in the product specification.

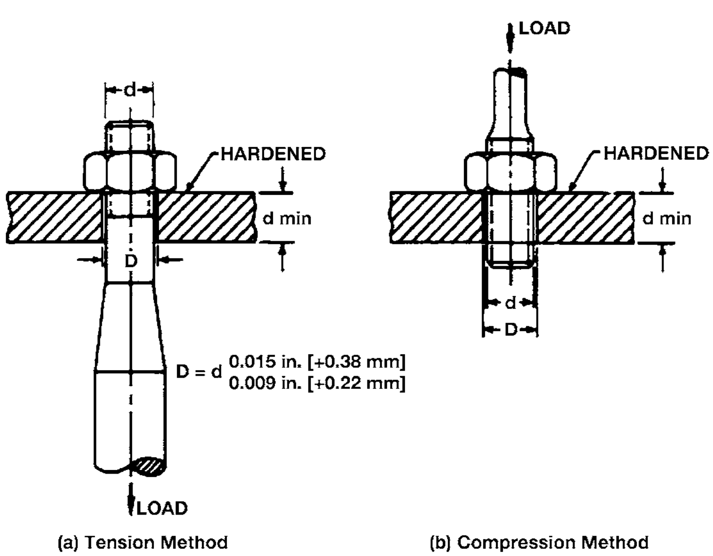

FIG. 1 Proof Load Testing—Nuts

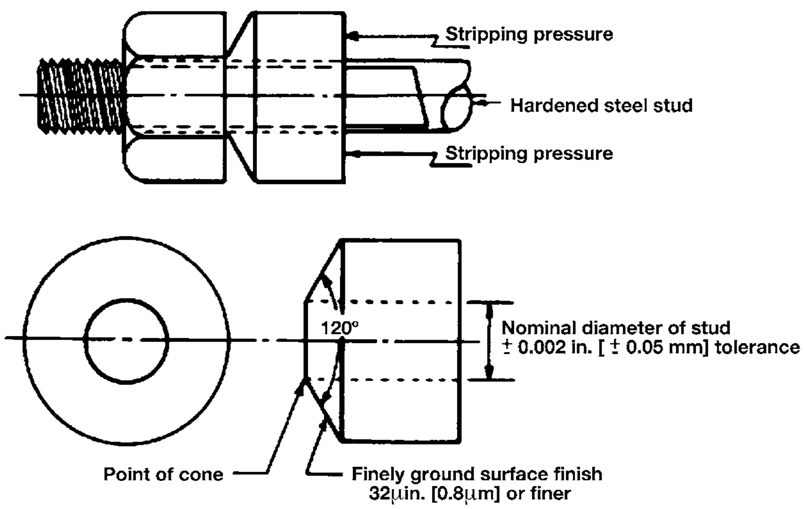

FIG. 2 Cone-Proof Test

12. Impact Requirements

12.1 The material shall conform to the impact requirements prescribed in the product specification.

12.2 Sampling for impact testing shall conform to the product specification.

12.3 The impact test specimen shall have the form and dimensions shown in Fig. 10 of Test Methods and Definitions A 370 for the Charpy V-notch specimen, Type A. The longitudinal axis of the specimen shall be parallel to the direction of rolling or, in the case of forgings, to the longest axis of the component the test bar represents. The notch shall be located on the test specimen surface which most closely approaches a radial direction. The base of the notch shall be as nearly as practicable perpendicular to the longest axis of the component.

13. Workmanship, Finish, and Appearance

13.1 The parts shall conform to the dimensions, tolerances and finish as specified on the purchaser's order or in the individual product specification.

13.2 *Bars*—Bars shall meet the dimensional requirements of Specifications A 29/A 29M or A 484/A 484M as applicable.

13.3 *Bolts, Screws, Studs, and Stud Bolts*—Fastener points shall be flat and chamfered or rounded at the option of the manufacturer. The length of the point on studs and stud bolts shall be not less than one nor more than two complete threads as measured from the extreme end parallel to the axis. Length of studs and stud bolts shall be measured from first thread to first thread. Bolts, studs, and bolting material shall be capable of passing inspection in accordance with Specification F 788/F 788M.

13.3.1 *Hex Bolts*—Unless otherwise specified in the purchase order heads shall be in accordance with the dimensions of ANSI B18.2.1 or B18.2.3.6M and the Heavy Hex screw series, should be used, except the maximum body diameter and radius of fillets may be the same as for the heavy hex bolt series. The body diameter and head fillet radius for sizes of heavy hex cap screws and bolts that are not shown in their respective tables in the ANSI specifications may be that shown in the corresponding hex cap screw and bolt tables respectively.

13.3.2 *Socket Heads*—Unless otherwise specified socket head fasteners shall be in accordance with ANSI B18.3 or the applicable metric series.

13.3.3 *Studs and Stud Bolts*—The dimensions and tolerances of studs and stud bolts shall be as specified by the purchaser or the product specification.

13.4 *External Threads*—Threads shall either be formed after heat treatment or heat treatment shall be performed in atmosphere control furnaces.

13.4.1 *Thread Form*—Unless otherwise specified external threads shall be in accordance with ANSI B1.1, Class 2A fit, or ANSI B1.13M, Class 6G fit.

13.4.2 *Inch Series*—Sizes 1 in. and smaller in diameter shall be coarse thread series, and those 1⅛ in. and larger in diameter shall be eight pitch thread series, unless otherwise specified.

13.5 *Nuts*—Unless otherwise specified nuts shall be hexagonal in shape and the American National Standard Heavy Hex Series shall be used. In addition nuts shall either be double chamfered or have a machined or forged washer face, at the option of the manufacturer, and shall conform to the angularity requirements of the applicable ANSI specification.

13.5.1 *Thread*—Unless otherwise specified threads in nuts shall be in accordance with ANSI B1.1 Class 2B fit or B1.13M Class 6H fit, and shall be gaged in accordance with ANSI B1.2 or B1.3M

13.5.2 *Inch Series*—Unless otherwise specified, nuts up to and including 1 in. in diameter shall be UNC Series Class 2B fit and nuts over 1 in. nominal size shall be 8 UN Series Class 2B fit.

13.6 If a scale-free bright finish is required, this shall be specified on the purchase order.

14. Decarburization

14.1 *Depth*—The depth of decarburization (total + partial) shall be determined after completion of all heat treatment and

TABLE 1 Cone Proof Load Using 120° Hardened Steel Cone—Inch[A]

Nominal Size, in.	Threads per inch	Stress Area, in.^{2}	Cone Proof Load, lbf — Based on Proof Stress, psi, Shown in Column Header Below: 120 000	130 000	135 000	150 000	175 000
¼	28	0.0364	4050	4375	4550	5050	5900
¼	20	0.0318	3525	3825	3975	4400	5150
5⁄16	24	0.0580	6300	6825	7100	7875	9200
5⁄16	18	0.0524	5700	6175	6400	7125	8300
⅜	24	0.0878	9350	10 125	10 525	11 700	13 625
⅜	16	0.0775	8250	8950	9300	10 300	12 050
7⁄16	20	0.1187	12 350	13 400	13 900	15 450	18 050
7⁄16	14	0.1063	11 100	12 000	12 450	13 850	16 150
½	20	0.1599	16 300	17 650	18 350	20 400	23 800
½	13	0.1419	14 500	15 700	16 300	18 100	21 100
9⁄16	18	0.203	20 200	21 900	22 800	25 300	29 500
9⁄16	12	0.182	18 200	19 700	20 400	22 700	26 500
⅝	18	0.256	25 000	27 000	28 100	31 200	36 400
⅝	11	0.226	22 000	23 900	24 800	27 500	32 100
¾	16	0.373	34 700	37 600	39 000	43 400	50 600
¾	10	0.334	31 000	33 600	35 000	38 800	45 200
⅞	14	0.509	45 000	48 800	50 600	56 400	65 600
⅞	9	0.462	40 800	44 200	46 000	51 200	59 600
1	12	0.663	55 600	60 400	62 600	69 600	81 200
1	8	0.606	51 000	55 200	57 200	63 600	74 200
1 ⅛	12	0.856	68 000	73 800	76 600	85 000	99 200
1 ⅛	8	0.790	62 800	68 000	70 600	78 600	91 600
1 ⅛	7	0.763	60 750	65 750	68 250	75 750	88 500
1 ¼	12	1.073	80 500	87 250	90 500	100 500	117 250
1 ¼	8	1.000	75 000	81 250	84 250	93 750	109 250
1 ¼	7	0.969	72 750	78 750	81 750	90 750	106 000
1 ⅜	12	1.315	92 750	100 500	104 250	116 000	135 250
1 ⅜	8	1.233	87 000	94 250	98 000	108 750	126 750
1 ⅜	6	1.155	81 500	88 250	91 500	101 750	118 750
1 ½	12	1.581	104 250	113 000	117 500	130 500	152 250
1 ½	8	1.492	98 500	106 750	110 750	123 000	143 500
1 ½	6	1.405	92 750	100 500	104 250	116 000	135 250

[A]Based upon the following equation (this equation should not be used for extrapolating values beyond the size ranges listed in this table) and rounded to nearest ½ ksi equivalent:

$$CPL = (1 - 0.30D) \times f \times As$$

where:
CPL = cone stripping proof load, lbf.,
D = nominal diameter of nut, in.,
f = minimum proof stress of nut, psi.,
As = tensile stress area of nut, in^2 = 0.7854 [D - 0.9743/n]^2, and
n = threads per inch.

shall not exceed the limits shown in Specification A 574, regardless of material being tested.

14.2 *Test Method*—The depth of decarburization shall preferably be determined by metallographic etching. The edge of the specimen shall be suitably prepared to preserve the original heat treated surface. The sample shall be polished, etched with a suitable solution (2 to 5 % Nital if carbon or alloy steel, Vilella's reagent if stainless steel, etc.), and examined under a microscope at 100x using an eyepiece graduated in 0.001–in. [0.025–mm] increments. The measured depth of any light etched band shall be taken as the decarburization depth.

14.2.1 *Microhardness Testing*—When the metallographic etch method of 14.2 renders results that are inconclusive, then the microhardness traverse method of Specification A 574 shall be employed. The depth of decarburization is denoted by that radial depth where the hardness decrease is more than the equivalent of three points HRA, when compared to the average microhardness of the base material at a depth equal to or less than 25 % of the diameter or thickness.

14.3 *Alternate*—Depth of decarburization may be determined on the threads of components rather than on the starting material.

15. Number of Tests

15.1 *Chemical Analysis*—One test per heat.

15.2 *Tension Tests, Bar, Rod, or Wire or Fasteners, or Both, Machined from Heat Treated Bar, Rod or Wire*—One test per lot (See 3.1.6).

TABLE 2 Cone Proof Load Using 120° Hardened Steel Cone—Metric[A]

Nominal Size, mm	Thread Pitch	Stress Area, mm^2	Cone Proof Load, kN Based on Proof Stress Shown in Column Header Below				
			825 MPa	895 MPa	930 MPa	1035 MPa	1205 MPa
M6	1	20.1	15.4	16.7	17.4	19.3	22.5
M8	1.25	36.6	27.3	29.6	30.8	34.3	39.9
M10	1.5	58.0	42.1	45.7	47.5	52.8	61.5
M12	1.75	84.3	59.5	64.5	67	74.5	87
M14	2	115	79	86	89.5	99.5	115.5
M16	2	157	104.5	113.5	117.5	131	152.5
M20	2.5	245	153	167	173	193	224
M22	2.5	303	184	200	208	231	269
M24	3	353	207	224	233	260	302
M27	3	459	256	278	289	322	374
M30	3.5	561	296	322	334	372	432
M36	4	817	382	416	432	480	558

[A]Based upon the following equation (this equation should not be used for extrapolating values beyond the size ranges listed in this table) and rounded to nearest 3.5 MPa equivalent:

$$CPL = (1 - 0.012D) \times f \times As \times 0.001$$

where:

CPL = Cone stripping proof load, kN,
D = Nominal diameter of nut, mm,
f = Minimum proof stress of nut, MPa,
As = Tensile stress area of nut, $mm^2 = 0.7854\ [D - 0.9382P]^2$, and
P = Thread pitch, mm.

15.3 *Tension Tests, Fasteners Produced as Defined in 8.6*—The number of machined specimens or full size fasteners tested shall be as follows:

Lot Size (pc)	Sample Size
50 and less	2
51 to 500	3
501 to 35 000	5
Over 35 000	8

15.4 *Decarburization Test, Carbon and Alloy Steel, Fasteners Produced as Defined in 8.6 and Studs Machined from Cold or Hot Rolled and Heat Treated Bar Whose Diameter Prior to Machining Threads is Within 0.06 in. [1.5 mm] in Diameter of the Maximum Thread Diameter*—One test per lot (see 3.1.6).

15.5 *Hardness Tests*:

15.5.1 *Hardness Tests, Bar, Rod, or Wire*—One test per lot.

15.5.2 *Hardness Tests, Fasteners*—The number of fasteners hardness tested per lot, regardless of production technique, shall be as shown in 15.3.

15.6 *Macroetch, Carbon and Alloy Steels Only*—One test per lot. A lot in this case is defined as a single diameter of a single heat or the largest diameter of a single heat.

15.7 *Impact Tests*—Three impact test specimens shall be made for each lot when impact testing is required by the product specification.

15.8 *Other Tests*—The number of tests shall be as specified by the purchaser or the individual product specification.

16. Retests and Rework

16.1 If the results of any tension test do not conform to the requirements specified in the product specification, retests are permitted as outlined in Test Methods and Definitions A 370. If the results of a tension test are less than specified because a flaw becomes evident in the test specimen during testing, a retest shall be allowed provided that the flaw is not attributable to ruptures, cracks, or flakes in the steel. Retesting shall be performed on twice the number of samples originally specified.

16.2 When the impact test acceptance requirements of the specification are not met, one retest of three additional specimens from the same test location may be performed. Each individual test value of the retested specimens shall be equal to or greater than the specified minimum average value.

16.3 Repair by welding is prohibited.

17. Inspection

17.1 The supplier shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification and the applicable product specification. Site inspection by the purchaser shall not interfere unnecessarily with the supplier's operations.

17.2 Personnel performing the nondestructive examination shall be qualified and certified in accordance with a written procedure conforming to ASNT Recommended Practice No. SNT-TC-1A (1988 or later) or another national standard that is acceptable to both the purchaser and the supplier.

18. Rejection and Rehearing

18.1 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed to between the supplier and the purchaser.

19. Certification

19.1 Certification shall include a statement that the material or parts, or both, were manufactured, sampled, tested, and inspected in accordance with the requirements of the individual product specification, including the specification number and year date of issue. In addition, the certification shall include the results of all tests required by this specification, the product specification, and the purchase order. The supplier shall provide additional specific information as required by the product specification or purchase order.

19.2 A certificate printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall also conform to any existing EDI agreement between the purchaser and the supplier.

19.3 Notwithstanding the absence of a signature, the organization submitting either the EDI transmission or paper copies of certificates of test is responsible for the content of the report.

20. Product Marking

20.1 Bars shall be marked in accordance with Specifications A 29/A 29M or A 484/A 484M as applicable.

20.2 Grade and manufacturer's identification symbols shall be applied to one end of studs ⅜ in. [10 mm] in diameter and larger and to the heads of bolts and screws ¼ in [6 mm] in diameter and larger. If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end of studs. Bolts and screws shall preferably be marked on top of the head. When necessary, bolts and screws may be marked on the side of the head provided the marking does not interfere with wrenchability or become damaged during tightening to the extent that legibility is lost. Products shall not be marked on the bearing surface or be marked in a way that alters the dimensions or geometric characteristics of the bearing surface.

20.3 Grade and manufacturer's identification symbols shall be applied to all nuts regardless of size.

20.4 Hollow forgings shall be marked with the heat number or heat symbol and grade.

20.5 When product is altered in a manner which changes specified requirements, it is the responsibility of the current certifying organization to ensure that the product marking is appropriately revised. This includes the removal of the name or symbol of the previous certifying organization.

20.6 *Dual Marking*—Product that meets all requirements of more than one grade within or between product specifications may be marked with both grade markings. The dual marking shall consist of the complete marking requirement for each grade, as required by the product specification, separated by a slash. For example, for Grade A 193 B7 and A 320 L7, the dual marking would be B7/L7.

21. Packaging, Package Marking and Loading for Shipment

21.1 Packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

22. Keywords

22.1 austenitic stainless steel; bolts, steel; fasteners, steel; nuts, steel; pressure vessel service; steel bars, alloy; steel bars, carbon; steel bars, stainless; steel bolting materials; stainless steel bolting materials; temperature service applications, high; temperature service applications, low; turbine materials

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order, in which event the specified tests shall be made before shipment of the product.

S50. Product Marking

S50.1 Grade and manufacturer's identification symbols shall be applied to one end of studs and to the heads of bolts of all sizes. If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.

S51. Stress Relieving

S51.1 A stress relieving operation shall follow straightening after heat treatment. The minimum stress relieving temperature shall be 100 °F [55 °C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

S52. Heat Analysis

S52.1 An analysis of each remelt ingot shall be made by the steel manufacturer to determine the percentages of those elements specified in the individual product specification. The chemical analysis thus determined shall conform to the requirements of the individual product specification.

S53. Sequential or Continuous Strand Casting

S53.1 When multiple heats of the same chemical composition range are sequentially strand cast, the heats shall be separated by an established procedure such that intermix material shall not be supplied.

S54. Bolts, Studs and Bolting Material for Dynamic Service

S54.1 Bolts, studs and bolting material for dynamic service shall be examined for surface discontinuities and decarburization.

S54.2 *Surface Discontinuities*

S54.2.1 The surface discontinuities shall conform to Specification F 788/F 788M and the additional limitations in S54.2.2.

S54.2.2 Thread lap inspection shall be performed in accordance with Specification F 788/F 788M Supplementary Requirement S50. The threads shall have no laps at the root, or on the flanks initiating or extending below the pitch line.

S54.2.3 Quench cracks of any depth, any length, or in any location are not permitted.

S54.2.4 Folds at the junction of the head and the shank are not permitted.

S54.3 *Decarburization*

S54.3.1 Decarburization tests shall be conducted as follows, with the same number of tests as the tension test:

S54.3.2 Section the thread area longitudinally through the axis, and mount and polish the cut face in accordance with Practice E 3. Use either optical or microhardness measurements for decarburization. In case of dispute, the microhardness method shall be used.

S54.3.3 For optical measurement, etch the metallographic section in 4 % Nital. Examine the surface of the etched sample under a microscope at 100X using a measuring eyepiece graduated in 0.001 in. (0.03 mm) increments, or on a ground glass screen or photomicrograph. There shall be no gross decarburization (clearly defined ferrite grains), and the depth of partial decarburization (light etching zone) anywhere below the pitch line shall be less than 5 % of the nominal thread height.

S54.3.4 For microhardness measurement, make hardness tests in accordance with Test Method E 384 on unetched metallographic sections using either a DPH 136° indenter and a 200-gf load, or a Knoop indenter and a 200-gf load. Take measurements at the minor diameter on the thread crest bisector to determine the base metal hardness. On the same or an adjacent thread, take measurements within 0.003 in. (0.08 mm) of the flank surface at the pitch line, and 0.003 in. (0.08 mm) below the thread root. These two hardness readings shall be equal to or greater than the base metal hardness minus 30 DPH or KHN.

S55. Magnetic Particle Examination

S55.1 The wet fluorescent magnetic particle examination method shall be applied to 100 % of the lot in accordance with Practice E 1444. Acceptance criteria shall be in accordance with S57.

S56. Liquid Penetrant Examination

S56.1 The fluorescent liquid penetrant examination method shall be applied to 100 % of the lot in accordance with Practice E 1417. Acceptance criteria shall be in accordance with S57.

S57. Acceptance Criteria

S57.1 Only indications, which have a dimension greater than 1⁄16 in., shall be considered relevant. A linear indication is one having a length greater than three times the width. A rounded indication is one of circular or elliptical shape with a length equal to or less than three times the width. All surfaces examined shall be free of the following:

S57.1.1 Relevant linear indications;

S57.1.2 Relevant rounded indications greater than 3⁄16 in.; and,

S57.1.3 Four or more relevant rounded indications in a line separated by 1⁄16 in. or less, edge to edge.

S58. Positive Material Identification Examination

S58.1 Bolting shall receive Positive Material Identification to ensure that the purchaser is receiving bolting of the correct material grade prior to shipment of the bolting. This examination is a method to assure that no material grade mix-up has happened during manufacturing and marking of bolting.

S58.2 Bolting shall receive a Positive Material Identification examination by Guide E 1916.

S58.3 The quantity examined shall be 100 % of the bolting.

S58.4 All bolting that are not of the correct material grade shall be rejected.

S58.5 The method of bolting marking after examination shall be agreed upon between the manufacturer and purchaser.

S59. Pressure Equipment Directive—Mechanical Testing

S59.1 Charpy impact testing shall be done at the lowest scheduled operating temperature, but not higher than 20 °C (68 °F).

S59.2 The frequency of impact testing shall be the same as that specified in the product specification for the tension test, with three individual Charpy test specimens for each required tension test.

S59.3 The minimum individual energy for the Charpy impact test shall be 20 ft-lb [27 J].

S59.4 The minimum elongation in the tension test shall be measured on a gage length of five times the diameter of the test specimen, and shall not be less than 14 %.

S59.5 Impact and tension test results shall be included in the product certification.

ANNEXES

(Mandatory Information)

A1. REQUIREMENTS FOR THE INTRODUCTION OF NEW MATERIALS

A1.1 New materials may be proposed for inclusion in specifications referencing this Specification of General Requirements subject to the following conditions:

A1.1.1 Application for the addition of a new grade to a specification shall be made to the chairman of the subcommittee which has jurisdiction over that specification.

A1.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable specification.

A1.1.3 The application shall be accompanied by test data as required by the applicable specification. Test data from a minimum of three test lots, as defined by the specification, each from a different heat, shall be furnished.

A1.1.4 The application shall provide recommendations for all requirements appearing in the applicable specification.

A1.1.5 The application shall state whether the new grade is covered by patent.

A2. CHANGES TO EXISTING GRADES

A2.1 When changes such as chemistry, heat treatment, or processing, or combinations thereof are proposed for grades in specifications under the purview of A01.22, it is the purview of the subcommittee to request additional data/tests. Testing required may include, but is not limited to, stress rupture, tensile, impact, and stress relaxation in order to validate that the changes have not adversely impacted those properties, even though the testing may not normally be required by the standard.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 962/A 962M – 07, that may impact the use of this specification. (Approved June 1, 2007).

(*1*) Added lot definition to 15.6.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 962/A 962M – 06, that may impact the use of this specification. (Approved February 1, 2007).

(*1*) Revised 20.2.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 962/A 962M – 04a, that may impact the use of this specification. (Approved November 1, 2006).

(*1*) Revised the Proof Load Test (originally 10.2) and added the Cone Proof Load Test as Section 11.

(2) Added Table 1, Table 2, Fig. 1, and Fig. 2.

Designation: A 961/A 961M – 07

Standard Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications[1]

This standard is issued under the fixed designation A 961/A 961M; 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 covers a group of common requirements that shall apply to steel flanges, forged fittings, valves, and parts for piping applications under any of the following individual product specifications:

Title of Specification	ASTM Designation
Forgings, Carbon Steel, for Piping Components	A 105/A 105M
Forgings, Carbon Steel, for General-Purpose Piping	A 181/A 181M
Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High Temperature Service	A 182/A 182M
Forgings, Carbon and Low Alloy Steel, Requiring Notch Toughness Testing for Piping Components	A 350/A 350M
Forged or Rolled 8 and 9 % Nickel Alloy Steel Flanges, Fittings, Valves, and Parts for Low-Temperature Service	A 522/A 522M
Forgings, Carbon and Alloy Steel, for Pipe Flanges, Fittings, Valves, and Parts for High-Pressure Transmission Service	A 694/A 694M
Flanges, Forged, Carbon and Alloy Steel for Low Temperature Service	A 707/A 707M
Forgings, Carbon Steel, for Piping Components with Inherent Notch Toughness	A 727/A 727M
Forgings, Titanium-Stabilized Carbon Steel, for Glass-Lined Piping and Pressure Vessel Service	A 836/A 836M

1.2 In case of conflict between a requirement of the individual product specification and a requirement of this general requirement specification, the requirements of the individual product specification shall prevail over those of this specification.

1.3 By mutual agreement between the purchaser and the supplier, additional requirements may be specified (see Section 4.1.2). The acceptance of any such additional requirements shall be dependent on negotiations with the supplier and must be included in the order as agreed upon between the purchaser and supplier.

1.4 The values stated in either inch-pound units or SI units (metric) are to be regarded separately as standard. Within the text and the tables, 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 (SI) of the product specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 105/A 105M Specification for Carbon Steel Forgings for Piping Applications
A 181/A 181M Specification for Carbon Steel Forgings, for General-Purpose Piping
A 182/A 182M Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings
A 350/A 350M Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 522/A 522M Specification for Forged or Rolled 8 and 9% Nickel Alloy Steel Flanges, Fittings, Valves, and Parts for Low-Temperature Service
A 694/A 694M Specification for Carbon and Alloy Steel Forgings for Pipe Flanges, Fittings, Valves, and Parts for High-Pressure Transmission Service
A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment
A 707/A 707M Specification for Forged Carbon and Alloy Steel Flanges for Low-Temperature Service
A 727/A 727M Specification for Carbon Steel Forgings for Piping Components with Inherent Notch Toughness

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] 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.

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

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 836/A 836M Specification for Titanium-Stabilized Carbon Steel Forgings for Glass-Lined Piping and Pressure Vessel Service
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A 967 Specification for Chemical Passivation Treatments for Stainless Steel Parts
A 991/A 991M Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
B 880 Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys
E 165 Test Method for Liquid Penetrant Examination
E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
E 709 Guide for Magnetic Particle Examination
E 1916 Guide for Identification and/or Segregation of Mixed Lots of Metals

2.2 *ASME Standard:*[3]
ASME Boiler and Pressure Vessel Code–Section IX

2.3 *Military Standard:*[4]
MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.4 *Manufacturer's Standardization Society Standard:*[5]
SP 25 Standard Marking System of Valves, Fittings, Flanges and Unions

3. Terminology

3.1 *Definitions*—For definitions of other terms used in this specification, refer to Terminology A 941.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bar*, *n*—a solid rolled or forged section that is long in relationship to its cross sectional dimensions, with a relatively constant cross section throughout its length and a wrought microstructure.

3.2.2 *certifying organization*, *n*—the company or association responsible for the conformance of, and marking of, the product to the specification requirements.

3.2.3 *fitting*, *n*—a component for non-bolted joints in piping systems.

3.2.4 *flange*, *n*—a component for bolted joints used in piping systems.

3.2.5 *forging*, *n*—the product of a substantially compressive hot or cold plastic working operation that consolidates the material and produces the required shape.

3.2.5.1 *Discussion*—The plastic working must be performed by a forging machine, such as a hammer, press, or ring rolling machine, and must deform the material to produce a wrought structure throughout the material cross section.

3.2.6 *seamless tubing*, *n*—a tubular product made without a welded seam.

3.2.6.1 *Discussion*—It is manufactured usually by hot working the material, and if necessary, by subsequently cold finishing the hot worked tubular product to produce the desired shape, dimensions and properties.

4. Ordering Information

4.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include, but are not limited to, the following:

4.1.1 Quantity,

4.1.2 Size and pressure class or dimensions, (tolerances and surface finishes should be included),

4.1.3 Specification number with grade or class, or both, as applicable, and year/date,

4.1.4 Supplementary requirements, and

4.1.5 Additional requirements.

5. Melting Process

5.1 Unless otherwise specified in the individual Product Specification, the steel shall be fully killed.

5.2 If a specific type of melting is required by the purchaser, it shall be stated on the purchase order.

5.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, such as electroslag remelting or vacuum remelting. If secondary melting is employed, the heat shall be defined as all of the ingot remelted from a single primary heat.

5.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The steel producer shall remove the transition material by an established procedure that positively separates the grades.

5.5 A sufficient discard shall be made from the source material to secure freedom from injurious porosity and shrinkage, and undue segregation.

6. Manufacture

6.1 The finished part shall be manufactured from a forging that is as close as practicable to the finished size or shape. Alternative starting materials may be used, but with the following exceptions and requirements.

6.1.1 *Bar*—Flanges, elbows, return bends, tees, and header tees shall not be machined directly from bar. Other hollow cylindrical shaped parts up to, and including, NPS 4 can be machined from bar provided that the axial length of the part is approximately parallel to the metal flow lines of the starting stock.

6.1.2 *Wrought Seamless Pipe and Tubing*—Flanges shall not be machined directly from seamless pipe or tubing. Other hollow cylindrical shaped parts can be machined from seamless pipe and tubing provided that the axial length of the part is approximately parallel to the metal flow lines of the starting stock.

[3] Available from the American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016–5990.

[4] Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[5] Available from the Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park Street, NW., Vienna, VA 22180.

7. Heat Treatment

7.1 Material requiring heat treatment shall be treated as specified in the individual product specification using the following procedures that are defined in more detail in Terminology A 941.

7.1.1 *Full Annealing*—Material shall be uniformly reheated to a temperature above the transformation range and, after holding for a sufficient time at this temperature, cooled slowly to a temperature below the transformation range.

7.1.2 *Solution Annealing*—Material shall be heated to a temperature that causes the chrome carbides to go into solution, and then, quenched in water or rapidly cooled by other means to prevent reprecipitation.

7.1.3 *Isothermal Annealing*—Isothermal annealing shall consist of austenitizing a ferrous alloy, and then, cooling to and holding within the range of temperature at which the austenite transforms to a relatively soft ferrite-carbide aggregate.

7.1.4 *Normalizing*— Material shall be uniformly reheated to a temperature above the transformation range, and subsequently, cooled in air at room temperature.

7.1.5 *Tempering and Post-Weld Heat Treatment*—Material shall be reheated to the prescribed temperature below the transformation range, held at temperature for the greater of 30 min or 1 h/in. [25.4 mm] of thickness at the thickest section and cooled in still air.

7.1.6 *Stress Relieving*— Material shall be uniformly heated to the selected stress relieving temperature. The temperature shall not vary from the selected temperature by more than ±25 °F [±14 °C].

7.1.7 *Quench and Temper*—Material shall be fully austenitized and quenched immediately in a suitable liquid medium. The quenched fittings shall be reheated to a minimum temperature of 1100 °F [590 °C] and cooled in still air.

8. Chemical Requirements

8.1 *Chemical Analysis*—Samples for chemical analysis and methods of analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

8.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of those elements specified in the individual product specification. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot, or the product of one remelted ingot, from each primary melt. The chemical analysis thus determined shall conform to the requirements of the individual product specification. Note that the product analysis (check analysis) tolerances are not to be applied to the Heat Analysis requirements.

8.3 *Product Analysis*—If a product analysis is performed it shall be in accordance with Test Methods, Practices, and Terminology A 751. Samples for analysis shall be taken from midway between center and surface of solid parts, midway between inner and outer surfaces of hollow parts, midway between center and surface of full-size prolongations or from broken mechanical test specimens. The chemical composition thus determined shall conform to the limits of the product specification, within the permissible variations of Table 1 or Table 2 of this specification, as appropriate for the grade being supplied.

9. Mechanical Requirements

9.1 *Method of Mechanical Tests*—All tests shall be conducted in accordance with Test Methods and Definitions A 370.

9.2 For the purpose of determining conformance to the product specification requirements, specimens shall be obtained from the production forgings, or from separately forged test blanks prepared from the stock used to make the finished product. In either case, mechanical test specimens shall not be removed until after all heat treatment is complete. If repair welding is performed, test specimens shall not be removed

TABLE 1 Product Analysis Tolerances for Higher Alloy and Stainless Steels[A]

Element	Limit or Maximum of Specified Range, Wt %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	0.030, incl	0.005
	over 0.030 to 0.20 incl.	0.01
Manganese	to 1.00 incl.	0.03
	over 1.00 to 3.00 incl.	0.04
	over 3.00 to 6.00	0.05
	over 6.00 to 10.00	0.06
Phosphorous	to 0.040, incl.	0.005
	over 0.040 to 0.20, incl.	0.010
Sulfur	to 0.030, incl.	0.005
Silicon	to 1.00, incl.	0.05
	over 1.00 to 5.00 incl.	0.10
Chromium	over 4.00 to 10.00 incl.	0.10
	over 10.00 to 15.00 incl.	0.15
	over 15.00 to 20.00 incl.	0.20
	over 20.00 to 27.50 incl.	0.25
Nickel	to 1.00 incl.	0.03
	over 1.00 to 5.00 incl.	0.07
	over 5.00 to 10.00 incl.	0.10
	over 10.00 to 20.00 incl.	0.15
	over 20.00 to 22.00 incl.	0.20
Molybdenum	to 0.20 incl.	0.01
	over 0.20 to 0.60 incl.	0.03
	over 0.60 to 2.00 incl.	0.05
	over 2.00 to 7.00 incl.	0.10
Titanium	all ranges	0.05
Columbium (Niobium) + Tantalum	all ranges	0.05
Columbium (Niobium)	0.05 to 0.20 incl.	0.01
Tantalum	to 0.10 incl.	0.02
Copper	to 0.50, incl.	0.03
	over 0.50 to 1.00, incl.	0.05
	over 1.00 to 3.00, incl.	0.10
	over 3.00 to 5.00, incl.	0.15
	over 5.00 to 10.00, incl.	0.20
Cobalt	0.05 to 0.20 incl.	0.01[B]
Nitrogen	to 0.19 incl	0.01
	over 0.19 to 0.25	0.02
	over 0.25 to 0.35	0.03
	over 0.35 to 0.45	0.04
	over 0.45 to 0.60	0.05
Aluminum	to 0.05 incl.	0.01
Vanadium	to 0.10 incl.	0.01
	over 0.10 to 0.25 incl.	0.02
Cerium	0.03 to 0.08	−0.005 +0.01

[A] This table does not apply to heat analysis.

[B] Product analysis limits for cobalt under 0.05 % have not been established and the producer should be consulted for those limits.

TABLE 2 Product Analysis Tolerances for Carbon and Low Alloy Steels

Element	Limit or Maximum of Specified Range, Wt %	Tolerance Over Maximum Limit or Under Minimum Limit for Size Ranges Shown, Wt %[A] 100 in.^{2} [645 cm^2], or less	Over 100 to 200 in.^{2} [645 to 1290 cm^2], incl	Over 200 to 400 in.^{2} [1290 to 2580 cm^2], incl	Over 400 in.^{2} [2580 cm^2]
Mn	to 0.90 incl	0.03	0.04	0.05	0.06
	over 0.90 to 1.00 incl	0.04	0.05	0.06	0.07
P	to 0.045 incl	0.005	0.010	0.010	0.010
S	to 0.045 incl	0.005	0.010	0.010	0.010
Si	to 0.40 incl	0.02	0.02	0.03	0.04
	over 0.40 to 1.00 incl	0.05	0.06	0.06	0.07
Cr	to 0.90 incl	0.03	0.04	0.04	0.05
	over 0.90 to 2.10 incl	0.05	0.06	0.06	0.07
	over 2.10 to 3.99 incl	0.10	0.10	0.12	0.14
Ni	to 0.50	0.03	0.03	0.03	0.03
Mo	to 0.20 incl	0.01	0.01	0.02	0.03
	over 0.20 to 0.40 incl	0.02	0.03	0.03	0.04
	over 0.40 to 1.15	0.03	0.04	0.05	0.06
Cu	to 1.00 incl	0.03	0.03	0.03	0.03
	over 1.00 to 2.00 incl	0.05	0.05	0.05	0.05
Ti	to 0.10	0.01	0.01	0.01	0.01
V	to 0.10 incl	0.01	0.01	0.01	0.01
	over 0.10 to 0.25 incl	0.02	0.02	0.02	0.02
	over 0.25 to 0.50 incl	0.03	0.03	0.03	0.03
C	0.03 and under	0.01	0.01	0.01	0.01
	over 0.030 to 0.75, incl.	0.02	0.02	0.02	0.02
Cb (Nb)	up to and incl. 0.14	0.02	0.02	0.02	0.02
Ca	up to and incl. 0.02	0.005	0.005	0.005	0.005
B	up to and incl. 0.01	0.0005	0.0005	0.0005	0.0005

[A] Cross-sectional area.

until after post-weld heat treatment is complete, unless permitted by the product specification. The locations from which test specimens are removed shall be in accordance with the Product Specification.

9.3 If separately forged test blanks are used, they shall be of the same heat of steel, be subjected to substantially the same reduction and working as the production forging they represent, be heat treated in the same furnace charge except as provided for in the reduced testing provisions of the product specification, under the same conditions as the production forging, and be of the same nominal thickness as the maximum heat treated thickness of the production forging.

9.4 When parts are machined from bar or seamless tubing, as permitted in 6.1.1 and 6.1.2, the mechanical properties may be determined for the parts from the starting material, if the parts have not been subjected to any subsequent thermal processing since the time of mechanical test.

10. Hardness Requirements

10.1 The part shall conform to the hardness requirements prescribed in the product specification.

10.2 Sampling for hardness testing shall conform to the product specification.

11. Tensile Requirements

11.1 Sampling for tensile testing shall conform to the Product Specification.

11.2 When the dimensions of the material to be tested will permit, the tension test specimens shall be machined to standard round 2-in. [50-mm] gage length tension test specimen described in Test Methods and Definitions A 370.

11.3 In the case of small sections, which will not permit taking of the standard test specimen described in 11.2, the subsize round specimen shall be machined as described in Test Methods and Definitions A 370. The tension test specimen shall be as large as feasible.

11.4 The results of the tensile tests shall conform to the tensile property requirements prescribed in the product specification.

11.5 If the results of tension tests do not conform to the requirements specified in the product specification, retests are permitted as outlined in Test Methods and Definitions A 370. If the results of any tension test specimen are less than specified because a flaw becomes evident in the test specimen during testing, a retest shall be allowed provided that the defect is not attributable to ruptures, cracks, or flakes in the steel.

12. Impact Requirements

12.1 The part shall conform to the impact requirements prescribed in the product specification.

12.2 Sampling for impact testing shall conform to the Product Specification.

12.3 If the average impact energy value meets the product specification requirements, but the energy value for one specimen is below the specified minimum value for individual specimens, a retest is permitted. This shall consist of two impact specimens from a location adjacent to, and on either side of, the specimen that failed. Each of the retested specimens must exhibit an energy value equal to or greater than the minimum average value required by the product specification.

13. Hydrostatic Test Requirements

13.1 Parts manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the finished part. Such tests shall be conducted by the supplier only when the hydrostatic test supplementary requirement in the product specification is invoked by the purchaser.

14. Rework

14.1 When one or more representative test specimens or retest specimens do not conform to the requirements specified in the product specification for the tested characteristic, the product may be reworked according to the following requirements:

14.1.1 If previously tested in the unheat treated condition, the product may be reworked by heat treatment, and subsequently retested, in accordance with the product specification.

14.1.2 If previously tested in the heat treated condition, the product may be reworked by reheat treatment, and subsequently retested, in accordance with the product specification.

15. Finish and Appearance

15.1 The parts shall conform to the dimensions, tolerances, and finish as specified on the purchaser's drawing or order.

15.2 The finished parts shall be cleaned to remove all scale and processing compounds prior to the final surface examination. The cleaning process shall not injure the surface finish, material properties, or the metallurgical structure. The cleaned parts shall be protected to prevent recontamination. Protective coatings on parts subsequently subjected to socket welds or butt welds shall be suitable for welding without removal of the coating. When specified in the purchase order, parts may be furnished in the as-formed or as-forged condition.

15.3 The parts shall be free of injurious imperfections as defined below. At the discretion of the inspector representing the purchaser, finished parts shall be subject to rejection if surface imperfections acceptable under 15.5 are not scattered, but appear over a large area.

15.4 *Depth of Injurious Imperfections*—Selected typical linear and other typical surface imperfections shall be explored for depth. When the depth encroaches on the minimum specified wall thickness of the finished part, such imperfections shall be considered injurious.

15.5 *Imperfections Not Classified as Injurious*—Surface imperfections not classified as injurious shall be treated as follows:

15.5.1 Seams, laps, tears, or slivers not deeper than 5 % of the actual wall thickness at the point of interest or 1⁄16 in. [1.6 mm], whichever is less, are acceptable. If deeper, these imperfections require removal, and shall be removed by machining or grinding.

15.5.2 Mechanical marks or abrasions and pits shall be acceptable without grinding or machining provided the depth does not exceed 1⁄16 in. [1.6 mm]. If such imperfections are deeper than 1⁄16 in. [1.6 mm] but do not encroach on the minimum wall thickness of the forging they shall be removed by machining or grinding to sound metal.

15.5.3 The wall thickness at the point of grinding, or at imperfections not required to be removed, shall be determined by deducting the amount removed by grinding, from the nominal finished wall thickness of the part. In any case, the wall thickness shall not be less than the specified minimum value.

16. Repair by Welding

16.1 The purchaser may require the supplier to submit proposed weld repairs for approval by invoking the appropriate supplementary requirement from the applicable product specification in the purchase order. If the purchaser does not require prior approval of proposed weld repairs, these repairs shall be permitted at the discretion of the supplier. All weld repairs shall be performed in accordance with the following limitations and requirements.

16.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

16.1.2 Defects shall be completely removed prior to welding by chipping or grinding to sound metal. Removal of these defects shall be verified by magnetic particle inspection in accordance with Test Method A 275/A 275M or Guide E 709 for the ferritic, martensitic, or ferritic/austenitic grades, or by liquid penetrant inspection in accordance with Test Method E 165 for ferritic, martensitic, or austenitic grades.

16.1.3 After repair welding, the welded area shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic particle or liquid penetrant inspection, as applicable.

16.1.4 Repair by welding shall not exceed 10 % of the surface area of the part, or 33⅓ % of the wall thickness of the finished product, or ⅜ in. [10 mm] deep at the location of the repair.

16.2 The weld repair shall conform to 9.2 and to the additional requirements, if any, invoked in the Product Specification.

17. Inspection

17.1 The supplier shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with the general specification and the applicable product specification. Site inspection by the purchaser shall not interfere unnecessarily with the supplier's operations.

18. Rejection and Rehearing

18.1 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon between the manufacturer and the purchaser.

18.2 Material that shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

19. Certification

19.1 Marking of the specification number and manufacturer's name or trademark on the parts, and printing of the same on test reports, when required, shall be certification that the parts have been furnished in accordance with the requirements of the specification.

19.2 Test reports shall be traceable to the heat identification on the parts. They shall contain the information specified by the Product Specification and the purchaser order. They shall include the specification number and year/date of issue.

19.3 A certificate printed from or used in electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpoint printed in the certifiers facility.

The content of the EDI transmitted document shall conform to any existing EDI agreement between the purchaser and supplier.

19.4 Not withstanding the absence of a signature, the organization submitting either a printed certificate or an EDI transmitted certificate is responsible for the content of the report.

20. Marking

20.1 Each piece shall be legibly marked with the specification number, grade and class, certifying organization's name or symbol, the heat number or heat identification, size, and service rating, if applicable. It is not required to mark the product with the specification year and date of issue. The Standard Marking System of Valves, Fittings, Flanges and Unions (SP 25) may be followed except the word "steel" shall not be substituted for the specification designation.

20.2 Product marking shall conform to the additional requirements, if any, invoked in the product specification or purchase order.

21. Packaging, Marking and Loading for Shipment

21.1 Packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

21.2 When specified in the contract or order, and or direct procurement by or direct shipment to the government, when Level A is specified, preservation, packaging, and packing shall be in accordance with Level A requirements of MIL-STD-163.

22. Keywords

22.1 alloy steel; carbon steel; fittings; flanges; forgings; general requirement; piping applications; pressure containing parts; stainless steel; temperature service applications—elevated; temperature service applications—high; valves

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order, in which event, the supplementary requirements specified shall be made at the place of manufacture, unless otherwise agreed upon, at the purchaser's expense. The test specified shall be witnessed by the purchaser's inspector before shipment of material, if so specified in the order. The rationale for beginning the section numbering with S50 is to eliminate the possibility of confusion with supplementary requirements existing in individual product specifications.

S50. Macroetch Test

S50.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted according to Method E 381.

S50.2 Acceptance limits shall be as agreed upon between the certifying organization and the purchaser.

S51. Heat Analysis

S51.1 When secondary melting processes are employed, a heat analysis shall be obtained from each remelted ingot, or the product of each remelted ingot, from each primary melt. The chemical analysis thus determined shall conform to the requirements of the individual product specification. Note that the product analysis (check analysis) tolerances are not to be applied to the heat analysis requirements.

S52. Product Analysis

S52.1 A product analysis shall be made from one randomly selected forging representing each heat. The results shall comply with the product analysis limits listed in the applicable product specification. For Specification A 182/A 182M grades of F20 and F58, results shall comply with the product analysis limits listed in Specification B 880.

S52.2 If the analysis fails to comply, each forging shall be checked or the lot rejected. All results shall be reported to the purchaser.

S53. Tension Tests

S53.1 In addition to the requirements of Section 9, one tension specimen shall be obtained from a representative forging from each heat at a location agreed upon between the certifying organization and the purchaser. The results of the test shall comply with the tensile property requirements listed in the applicable product specification and shall be reported to the purchaser.

S54. Impact Tests

S54.1 In addition to the requirements of Section 9, three CVN impact energy specimens shall be obtained from a representative forging from each heat at a location agreed upon between the certifying organization and the purchaser.

S54.2 The purchaser shall supply the impact test temperature and the required minimum requirements for the test, including the lowest single absorbed energy for a single specimen if an average absorbed energy value is required. The lateral expansion values and the fracture appearance of the specimens as percentage ductile fracture shall be reported for information if these parameters are not part of the acceptance requirements.

S55. Magnetic Particle Examination

S55.1 All accessible surfaces of the finished forging shall be examined by a magnetic particle method. The method shall be in accordance with Test Method A 275/A 275M. Acceptance limits shall be as agreed upon between the certifying organization and the purchaser.

S56. Liquid Penetrant Examination

S56.1 All accessible surfaces shall be examined by a liquid penetrant method in accordance with Test Method E 165.

Acceptance limits shall be as agreed upon between the certifying organization and the purchaser.

S57. Hydrostatic Testing

S57.1 A hydrostatic test at a pressure agreed upon between the certifying organization and the purchaser shall be applied by the certifying organization.

S58. Repair Welding

S58.1 No repair welding shall be permitted without prior approval of the purchaser. If permitted, the restrictions of Section 16 shall apply.

S59. Electropolished Austenitic and Ferritic–Austenitic Grades

S59.1 All electropolished austenitic and ferritic–austenitic products shall be of a cleanliness in accordance with Specification A 967.

S59.2 Details concerning which test method of Specification A 967 are to be a matter of agreement between the manufacturer and the purchaser.

S60. Positive Material Identification Examination

S60.1 Forgings shall receive positive material identification to ensure that the purchaser is receiving forgings of the correct material grade prior to shipment of the forgings. This examination is a method to ensure that no material grade mix-up has occurred during the manufacturing and marking of the forgings.

S60.2 Forgings shall receive a positive material identification examination in accordance with Guide E 1916.

S60.3 The quantity examined shall be 100 % of the forgings.

S60.4 All forgings that are not of the correct material grade shall be rejected.

S60.5 The method of forging marking after examination shall be agreed upon between the manufacturer and the purchaser.

S61. Heat Treatment in the Working Zone of a Surveyed Furnace

S61.1 Material shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A 991/A 991M, provided that such working zone was established using a variation of 25 °F [14 °C] or less from the furnace set point.

S61.2 The test report shall indicate that S61 applies.

S62. Requirements for Carbon Steel Products for Concentrated Hydrofluoric Acid Service

S62.1 Products shall be provided in the normalized heat-treated condition.

S62.2 The maximum carbon equivalent based on heat analysis shall be as follows:

Maximum section thickness less than or equal to 1 in.	CE maximum = 0.43
Maximum section thickness greater than 1 in.	CE maximum = 0.45

S62.3 Determine the carbon equivalent (CE) as follows:

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

S62.4 Vanadium and Niobium maximum content based on heat analysis shall be:

Maximum Vanadium = 0.02 wt %
Maximum Niobium[A] = 0.02 wt %
Maximum Vanadium plus Niobium[A] = 0.03 wt %

[A]Niobium = Columbium

S62.5 The maximum composition based on heat analysis of Ni + Cu shall be 0.15 wt %.

S62.6 The minimum C content based on heat analysis shall be 0.18 wt %. The maximum C content shall be as specified in the appropriate material specification.

S62.7 Repair welds shall not be made with E60XX electrodes. Use of E70XX electrodes is recommended, and the resulting weld chemistry should meet the same chemistry criteria as the base metal as listed above.

S62.8 In addition to the requirements of product marking of the specification, a "HF-N" stamp or marking shall be provided on each component to identify that component complies with this supplementary requirement.

S63 Pressure Equipment Directive—Mechanical Testing

S63.1 Charpy impact testing shall be done at the lowest scheduled operating temperature but not higher than 68 °F [20 °C].

S63.2 The frequency of impact testing shall be the same as that specified in the product specification for the tension test, with three individual Charpy test specimens for each required tension test.

S63.3 The minimum impact absorption energy for the Charpy test specimen shall be at least 20 ft/lb [27 J].

S63.4 The minimum elongation in the tension test shall be measured on a gage length of five times the diameter of the test specimen, and it shall not be less than 14 %.

S63.5 Impact and tension test results shall be included in the product certification.

ANNEX

(Mandatory Information)

A1. REQUIREMENTS FOR THE INTRODUCTION OF NEW MATERIALS

A1.1 New materials may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A1.1.1 Application for the addition of a new grade to a specification shall be made to the chairman of the subcommittee, which has jurisdiction over that specification.

A1.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable specification.

A1.1.3 The application shall be accompanied by test data as required by the applicable specification. Test data from a minimum of three test lots, as defined by the specification, each from a different heat, shall be furnished.

A1.1.4 The application shall provide recommendations for all requirements appearing in the applicable specification.

A1.1.5 The application shall state whether or not the new grade is covered by patent.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 961/A 961M – 05, that may impact the use of this specification. (Approved February 1, 2007)

(*1*) Deleted the term "ASTM" in 19.1 and 20.1.

Designation: A 960/A 960M – 07

Standard Specification for Common Requirements for Wrought Steel Piping Fittings[1]

This standard is issued under the fixed designation A 960/A 960M; 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 covers a group of common requirements that shall apply to wrought steel piping fittings covered in any of the following individual product specifications or any other ASTM specification that invokes this specification or portions thereof:

Title of Specification	ASTM Designation
Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures	A 234/A 234M
Specification for Wrought Austenitic Stainless Steel Piping Fittings	A 403/A 403M
Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service	A 420/A 420M
Specification for Butt-Welding, Wrought-Carbon Steel, Piping Fittings with Improved Notch Toughness	A 758/A 758M
Specification for As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperatures	A 774/A 774M
Specification for Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings	A 815/A 815M
Specification for Heat-Treated Carbon Steel Fittings for Low-Temperature and Corrosive Service	A 858/A 858M
Specification for Wrought High-Strength Low-Alloy Steel Butt-Welded Fittings	A 860/A 860M

1.2 In case of conflict between a requirement of the individual product specification and a requirement of this general requirement specification, the requirements of the individual product specification shall prevail over those of this specification.

1.3 By mutual agreement between the purchaser and the supplier, additional requirements may be specified (See 4.1.7). The acceptance of any such additional requirements shall be dependent on negotiations with the supplier and must be included in the order as agreed upon by the purchaser and supplier.

1.4 The values stated in either inch-pound units or SI units [metric] are to be regarded separately as standard. Within the text and the tables, 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 [SI] of the product specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 29/A 29M Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for

A 234/A 234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings

A 403/A 403M Specification for Wrought Austenitic Stainless Steel Piping Fittings

A 420/A 420M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 758/A 758M Specification for Wrought-Carbon Steel Butt-Welding Piping Fittings with Improved Notch Toughness

A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

A 774/A 774M Specification for As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperatures

A 815/A 815M Specification for Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings

A 858/A 858M Specification for Heat-Treated Carbon Steel Fittings for Low-Temperature and Corrosive Service

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved Feb. 1, 2007. Published February 2007. Originally approved in 1996. Last previous edition approved in 2006 as A 960/A 960M–06.

[2] 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.

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

A 860/A 860M Specification for Wrought High-Strength Low-Alloy Steel Butt-Welding Fittings
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A 967 Specification for Chemical Passivation Treatments for Stainless Steel Parts
E 165 Test Method for Liquid Penetrant Examination
E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
E 709 Guide for Magnetic Particle Examination
E 1916 Guide for Identification and/or Segregation of Mixed Lots of Metals

2.2 *Military Standard:*[3]
MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

2.3 *Manufacturer's Standardization Society Standards:*[4]
MSS-SP-25 The Standard Marking System of Valves, Fittings, Flanges and Unions
MSS-SP-43 Standard Practice for Light Weight Stainless Steel Butt-Welding Fittings
MSS-SP-75 Specification for High Test Wrought Butt-Welding Fittings
MSS-SP-79 Socket Welding Reducer Inserts
MSS-SP-95 Swage(d) Nipples and Bull Plugs

2.4 *American Society of Nondestructive Testing:*[5]
SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

2.5 *ASME Standards:*[6]
B16.9 Steel Butt-Welding Fittings
B16.11 Forged Steel Fittings, Socket Welding and Threaded
Section IX Welding Qualifications

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *bar*—a solid section that is long in relationship to its cross sectional dimensions, with a relatively constant cross section throughout its length. (See Specification A 29/A 29M for definitions relating to the production of hot wrought and cold finished bars.)

3.1.2 *certifying organization*—the company or association responsible for the conformance of, the marking of, and the certification of the product to the specification requirements.

3.1.3 *fitting*—a component for non-bolted joints used in piping systems and pressure vessels.

3.1.4 *flange*—a component for bolted joints used in piping systems and pressure vessels.

3.1.5 *forging*—the product of a substantially compressive hot or cold plastic working operation that consolidates the material and produces the required shape.

3.1.6 *Discussion*—The plastic working must be performed by a forging machine, such as a hammer, press, or ring rolling machine and must deform the material to produce an essentially wrought structure throughout the material cross section.

3.2 *Definitions*—For definitions of other terms used in this specification, refer to Terminology A 941.

4. Ordering Information

4.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the following:

4.1.1 Quantity,

4.1.2 Description of fitting and nominal dimensions (standard or special),

4.1.3 Steel composition by grade and class designation,

4.1.4 Construction, seamless or welded (unless seamless or welded construction is specified by the purchaser, either may be furnished at the option of the supplier),

4.1.5 Specification number (including the year/date of issue),

4.1.6 Supplementary requirements, and

4.1.7 Additional requirements.

5. Material

5.1 The material for fittings shall consist of forgings, bars, plates and seamless or welded tubular products.

5.2 The steel shall conform to the chemical requirements of the individual product specification and may be made from any process.

5.3 Ferritic steels shall be fully killed.

5.4 If secondary melting is employed, the heat shall be defined as all ingots remelted from a primary heat.

6. Manufacture

6.1 Forging or shaping operations may be performed by any of the methods included in the individual product specification.

6.2 Hollow cylindrically shaped parts up to and including NPS 4 may be machined from bar or seamless tubular material provided the axial length of the part is approximately parallel to the axial length of the fitting. Elbows, return bends, tees and header tees shall not be machined directly from bar stock.

6.3 Fittings, after forming at an elevated temperature, shall be cooled to a temperature below the critical range under suitable conditions to prevent injury by cooling too rapidly.

6.4 All classes of fittings shall have the welders, welding operators, and welding procedures qualified under the provision of Section IX of the ASME Boiler and Pressure Vessel Code except that welds from the original pipe manufacturer made without the addition of filler metal do not require such qualification.

7. Heat Treatment

7.1 Fittings requiring heat treatment shall be treated as specified in the individual product specification using the following procedures:

7.1.1 *Full Annealing*—Fittings shall be uniformly reheated to a temperature above the transformation range and, after holding for a sufficient time at this temperature, cooled slowly to a temperature below the transformation range.

[3] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.

[4] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602.

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

[6] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

7.1.2 *Solution Annealing*—Fittings shall be heated to a temperature that causes the carbides to go into solution and then quenched in water or rapidly cooled by other means to prevent reprecipitation.

7.1.3 *Isothermal Annealing*—Isothermal annealing shall consist of austenitizing a ferrous alloy and then cooling to and holding within the range of temperature at which the austenite transforms to a relatively soft ferrite-carbide aggregate.

7.1.4 *Normalizing*—Fittings shall be uniformly reheated to a temperature above the transformation range and subsequently cooled in air at room temperature.

7.1.5 *Tempering and Post-Weld Heat Treatment*—Fittings shall be reheated to the prescribed temperature below the transformation range, held at temperature for the greater of ½ h or 1 h/in. [25.4 mm] of thickness at the thickest section and cooled in still air.

7.1.6 *Stress Relieving*—Fittings shall be uniformly heated to the selected stress relieving temperature. The temperature shall not vary from the selected temperature by more than ± 25 °F [± 14 °C].

7.1.7 *Quench and Temper*—Fittings shall be fully austenitized and immediately quenched in a suitable liquid medium. The quenched fittings shall be reheated to a minimum temperature of 1100 °F [590 °C] and cooled in still air.

8. *Chemical Requirements* Chemical Requirements

8.1 *Chemical Analysis*—Samples for chemical analysis and methods of analysis shall be in accordance with Test Methods, Practices and Terminology A 751 for Chemical Analysis of Steel Products.

8.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of those elements specified in the individual product specification. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot of each primary melt. The chemical analysis thus determined shall conform to the requirements of the individual product specification. Note that the product analysis (check analysis) tolerances are not to be applied to the heat analysis requirements.

8.2.1 For steels ordered under product specifications referencing this specification of general requirements, the steel shall not contain an unspecified element, other than nitrogen for stainless steels, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS or grade designation in a table of chemical requirements within any specification listed within the scope as being covered by this specification.

8.3 *Product Analysis*—If a product analysis is performed it shall be in accordance with Test Methods, Practices, and Terminology A 751. The chemical composition thus determined shall conform to limits of the product specification, within the permissible variations of Table 1 or Table 2 of this specification, as appropriate for the grade being supplied.

TABLE 1 Product Analysis Tolerances for Low Alloy and Carbon Steels[A]

Elements	Limit, or Maximum of Specified Range, %	Permissible Variations Over Maximum Limit or Under Minimum Limit, %
Carbon	0.30 and under	0.01
	over 0.30 to 0.75, incl	0.02
	over 0.75	0.03
Manganese	0.90 and under	0.03
	over 0.90 to 2.10, incl	0.04
Phosphorus	over maximum only	0.005
Sulfur	0.060 and under	0.005
Silicon	0.40 and under	0.02
	over 0.40 to 2.20, incl	0.05
Nickel	1.00 and under	0.03
	over 1.00 to 2.00, incl	0.05
	over 2.00 to 5.30, incl	0.07
	over 5.30 to 10.00, incl	0.10
Chromium	0.90 and under	0.03
	over 0.90 to 2.10, incl	0.05
	over 2.10 to 3.99, incl	0.10
Molybdenum	0.20 and under	0.01
	over 0.20 to 0.40, incl	0.02
	over 0.40 to 1.15, incl	0.03
Vanadium	0.10 and under	0.01
	over 0.10 to 0.25, incl	0.02
	over 0.25 to 0.50, incl	0.03
	minimum value specified, under minimum limit only	0.01
Columbium (Niobium)	Up to and incl 0.14	0.02
	0.15 to 0.50, incl	0.06
Titanium	Up to and incl 0.85	0.05
Aluminum	0.10 and under	0.03
	over 0.10 to 0.20, incl	0.04
	over 0.20 to 0.30, incl	0.05
	over 0.30 to 0.80, incl	0.07
	over 0.80 to 1.80, incl	0.10
Lead[B]	0.15 to 0.35, incl	0.03
Copper	to 1.00 incl	0.03
	over 1.00 to 2.00, incl	0.05

[A] Chrome content less than 4.00.
[B] Product analysis tolerance for lead applies both over and under to a specified range of 0.15 to 0.35 %.

9. Mechanical Requirements

9.1 *Method of Mechanical Test*—All tests shall be conducted in accordance with Test Methods and Definitions A 370.

9.2 The test specimen shall represent all material from the same heat and heat treatment load whose maximum thicknesses do not exceed the thickness of the test specimen or blank by more than ¼ in. [6 mm].

9.3 One tension test at room temperature shall be made in accordance with 9.2 from each heat in each heat treatment load.

9.3.1 If heat treatment is performed in either a continuous or batch type furnace controlled within ± 25 °F [± 14 °C] of the required heat treatment temperature and equipped with recording pyrometers so that complete records of heat treatment are available, and if the same heat treating cycles are used on the material represented by the tension test, then one tension test from each heat shall be required, instead of one tension test from each heat in each heat treatment load in accordance with 9.2.

9.4 *Retest*—When a retest is permitted by the product specification, it shall be performed on twice the number of representative specimens that were originally nonconforming. When any retest specimen does not conform to the product specification requirements for the characteristic in question, the

TABLE 2 Product Analysis Tolerances for Higher Alloy and Stainless Steels[A]

Element	Upper Limit of Maximum of Specified Range, %	Tolerances Over the Maximum (Upper Limit) or Under the Minimum (Lower Limit)
Carbon	to 0.010, incl	0.002
	over 0.010 to 0.030, incl	0.005
	over 0.030 to 0.20, incl	0.01
	over 0.20 to 0.80, incl	0.02
	over 0.80 to 1.20, incl	0.03
Manganese	to 1.00, incl	0.03
	over 1.00 to 3.00, incl	0.04
	over 3.00 to 6.00, incl	0.05
	over 6.00 to 10.00, incl	0.06
	over 10.00 to 15.00, incl	0.10
	over 15.00 to 20.00, incl	0.15
Phosphorus	to 0.040, incl	0.005
	over 0.040 to 0.20, incl	0.010
Sulfur	to 0.040, incl	0.005
	over 0.040 to 0.20, incl	0.010
	over 0.20 to 0.50, incl	0.020
Silicon	to 1.00, incl	0.05
	over 1.00 to 3.00, incl	0.10
	over 3.00 to 6.00, incl	0.15
Chromium	over 4.00 to 10.00, incl	0.10
	over 10.00 to 15.00, incl	0.15
	over 15.00 to 20.00, incl	0.20
	over 20.00 to 30.00, incl	0.25
Nickel	to 1.00, incl	0.03
	over 1.00 to 5.00, incl	0.07
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 20.00, incl	0.15
	over 20.00 to 30.00, incl	0.20
	over 30.00 to 40.00, incl	0.25
	over 40.00	0.30
Molybdenum	over 0.20 to 0.60, incl	0.03
	over 0.60 to 2.00, incl	0.05
	over 2.00 to 7.00, incl	0.10
	over 7.00 to 15.00, incl	0.15
	over 15.00 to 30.00, incl	0.20
Titanium	to 1.00, incl	0.05
	over 1.00 to 3.00, incl	0.07
	over 3.00	0.10
Columbium	to 1.50, incl	0.05
Tantalum	to 0.10, incl	0.02
Copper	to 0.50, incl	0.03
	over 0.50 to 1.00, incl	0.05
	over 1.00 to 3.00, incl	0.10
	over 3.00 to 5.00, incl	0.15
	over 5.00 to 10.00, incl	0.20
Aluminum	to 0.15, incl	−0.005 +0.01
	over 0.15 to 0.50, incl	0.05
	over 0.50 to 2.00, incl	0.10
	over 2.00 to 5.00, incl	0.20
	over 5.00 to 10.00, incl	0.35
Nitrogen	to 0.02, incl	0.005
	over 0.02 to 0.19, incl	0.01
	over 0.19 to 0.25, incl	0.02
	over 0.25 to 0.35, incl	0.03
	over 0.35 to 0.45, incl	0.04
	over 0.45	0.05
Vanadium	to 0.50, incl	0.03
	over 0.50 to 1.50, incl	0.05
Cerium	to 0.20, incl	0.01
Tungsten	to 0.50, incl	0.20
	over 0.50–1.00, incl	0.30
	over 1.00–2.00, incl	0.50
	over 2.00–4.00, incl	0.60

[A] Chrome content 4.00 or greater.

lot represented by that specimen shall be rejected or reworked in accordance with Section 14.

9.4.1 If the results of the tension test do not conform to the requirements specified in the product specification, retests are permitted as outlined in Test Methods and Definitions A 370. If the results of any tension test specimen are less than specified because a flaw becomes evident in the test specimen during testing, a retest shall be allowed provided that the defect is not attributable to ruptures, cracks, or flakes in the steel.

9.4.2 If the average impact energy value meets the product specification requirements, but one energy value is below the specified minimum value for individual specimens, a retest is permitted. The retest shall be conducted in accordance with Test Methods and Definitions A 370.

9.5 For the purpose of determining conformance to the product specification requirements, specimens shall be obtained from a finished product, or from production material that is in the same condition of working and heat treatment as the production material.

10. Hardness Requirements

10.1 The part shall conform to the hardness requirements prescribed in the product specification.

10.2 Sampling for hardness testing shall conform to the product specification.

11. Tensile Requirements

11.1 The part shall conform to the tensile property requirements prescribed in the product specification.

11.2 Sampling for tensile testing shall conform to the product specification.

11.3 When the dimensions of the material to be tested will permit, the tension test specimens shall be machined to the form and dimensions of the standard 2-in. [50-mm] gage length tension test specimens described in Test Methods and Definitions A 370.

11.3.1 In the case of small sections, which will not permit taking the standard test specimen described in 11.3, the subsize round or strip specimen shall be machined as described in Test Methods and Definitions A 370. The tension test specimen shall be as large as feasible.

12. Impact Requirements

12.1 The part shall conform to the impact requirements prescribed in the product specification.

12.2 Sampling for impact testing shall conform to the product specification.

13. Hydrostatic Test Requirements

13.1 Parts manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the specified matching pipe of equivalent material. Such a test shall be conducted only when specified in the purchase order or when the hydrostatic test Supplementary Requirement is invoked by the purchaser.

14. Rework

14.1 When one or more representative test specimens or retest specimens do not conform to the requirements specified in the product specification for the tested characteristic, the lot of material represented by the test specimen may be reworked according to the following requirements.

14.1.1 If previously tested in the untreated condition, the product may be reworked by heat treatment, and subsequently retested, in accordance with the product specification.

14.1.2 If previously tested in the heat treated condition, the product may be reworked by reheat treatment, and subsequently retested, in accordance with the product specification.

15. Finish and Appearance

15.1 The parts shall conform to the dimensions, tolerances and finish as specified in the purchaser's order. Parts ordered to the requirements of an ASTM specification shall conform to the requirements of the individual product specification.

15.2 The surface finish shall allow the detection of imperfections that can be disclosed by visual inspection. Where necessary the finished parts shall be cleaned to remove all loose scale and processing compounds prior to the final surface examination. The cleaning process shall not injure the surface finish, material properties, or the metallurgical structure. The cleaned parts shall be protected to prevent recontamination. Protective coatings on parts subsequently subjected to socket welds or butt welds shall be suitable for welding without removal of the coating. When specified in the purchase order, parts may be furnished in the as-formed condition.

15.3 Fittings supplied under this specification shall be examined visually. Selected typical surface discontinuities shall be explored for depth. Unless otherwise specified in the purchase order, the following shall apply.

15.3.1 Fittings conforming to ASME B16.9 and MSS-SP-43 shall be free of surface discontinuities that penetrate more than 5 % of the specified nominal wall thickness, except as defined in 15.3.3 and 15.3.4. Fittings conforming to ASME B16.11 and MSS-SP-79 shall be free of surface discontinuities that penetrate more than 5 % of the actual wall thickness at the point of interest, or 1⁄16 in. [1.6 mm], whichever is less, except as defined in 15.3.4.

15.3.2 Surface discontinuities deeper than 5 % of the specified nominal wall thickness, except as defined in 15.3.3 and 15.3.4, shall be removed by the manufacturer by machining or grinding to sound metal, and the repaired areas shall blend smoothly into the contour of the finished fitting. Except for fittings conforming to MSS-SP-75, the wall thickness at all points shall be at least the specified minimum wall thickness, or 87½ % of the specified nominal wall thickness and the diameters shall be within the limits specified in the applicable dimensional standards.

15.3.3 Surface checks (fish scale) deeper than 1⁄64 in. [0.4 mm] shall be removed.

15.3.4 Mechanical marks deeper than 1⁄16 in. [1.6 mm] shall be removed.

15.3.5 When the removal of a surface discontinuity reduces the wall thickness below the specified minimum wall thickness at any point, the fitting shall be subject to rejection or to repair as provided in Section 16.

16. Repair by Welding

16.1 The purchaser may require the supplier to submit proposed weld repairs for approval by invoking the appropriate Supplementary Requirement in the purchase order.

16.2 If the purchaser does not require prior approval of the proposed weld repairs, these repairs shall be permitted at the discretion of the supplier. All weld repairs shall be performed in accordance with the following limitations and requirements.

16.2.1 The welding procedure, welders and operators shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. The composition of the weld deposit shall be compatible with the composition of the material being welded.

16.2.2 Defects shall be completely removed prior to welding by machining, chipping or grinding to sound metal. Removal of these defects shall be verified by magnetic particle examination in accordance with Guide E 709 or liquid penetrant inspection in accordance with Test Method E 165, as applicable.

16.2.3 After repair welding, the welded area shall be machined or ground smooth to the original contour and shall be completely free of defects as verified by magnetic particle examination in accordance with Guide E 709 or liquid penetrant inspection in accordance with Test Method E 165, as applicable.

16.2.4 Repair welding shall not exceed 10 % of the external surface area of the part, or 33⅓ % of the wall thickness of the finished product, or ⅜ in. [10 mm] deep maximum at the location of the repair, without prior approval of the purchaser.

16.2.5 Weld repaired material or parts, or both, shall be marked "RW" when required by the product specification.

16.3 The weld repair shall conform to the additional requirements, if any, invoked in the product specification.

17. Inspection

17.1 The supplier shall provide the purchaser's inspector with all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification and the applicable product specification. Site inspection by the purchaser shall not interfere unnecessarily with the supplier's operations.

18. Rejection and Rehearing

18.1 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed to between the supplier and the purchaser.

19. Marking

19.1 Each piece shall be legibly marked with the specification designation, grade and class, certifying organization's name or symbol, the heat number or heat identification, size, and schedule or thickness, if applicable. It is not required to mark the product with the specification year and date of issue. The Standard Marking System of Valves, Fittings, Flanges and Unions (MSS-SP-25) of the Manufacturer's Standardization Society of the Valve and Fittings Industry may be followed except the word "steel" shall not be substituted for the specification designation.

19.2 Product marking shall conform to the additional requirements, if any, invoked in the product specification.

20. Certification

20.1 Application of the specification designation and other identification marks as required in Section 19 shall be the certification that the material or parts, or both, have been furnished in accordance with the requirements of the specification.

20.2 When test reports are required, they shall include the year/date of issue, and shall be traceable to the part represented. In addition, the certification shall include the results of all tests required by this specification, the product specification, and the purchase order. The manufacturer, and any subsequent suppliers, shall provide the specific information required by the product specification and the purchase order.

20.3 A certificate printed from or used in electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall conform to any existing EDI agreement between the purchaser and the supplier.

20.4 Not withstanding the absence of a signature, the organization submitting either a printed certificate or an EDI transmitted certificate is responsible for the content of the report.

21. Packaging, Marking and Loading for Shipment

21.1 Packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

21.2 When specified in the contract or order, and or direct procurement by or direct shipment to the government, when Level A is specified, preservation, packaging, and packing shall be in accordance with Level A requirements of MIL-STD-163.

22. Keywords

22.1 austenitic stainless steel; corrosive service applications; ferritic/austenitic stainless steel; ferritic stainless steel; high strength low alloy steel; martensitic stainless steel; piping applications; pressure containing parts; pressure vessel service; stainless steel fittings; temperature service applications-elevated; temperature service applications-low; temperature service applications-moderate

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order, in which event, the supplementary requirements specified shall be made at the place of manufacture, unless otherwise agreed upon, at the purchaser's expense. The test specified shall be witnessed by the purchaser's inspector before shipment of material, if so specified in the order. The rationale for beginning the section numbering with S50 is to eliminate the possibility of confusion with supplementary requirements existing in individual product specifications.

S50. Product Analysis (See Note S50.1)

S50.1 A product analysis shall be made from each heat of base metal and, if of welded construction, from each lot number of welding material of the fittings offered for delivery. The analysis shall conform to the requirements specified in Section 8.

S51. Tension Test (See Note S50.1)

S51.1 One tension test shall be made on one fitting or representative test piece (See Note S50.2) per lot (See Note S50.3) of fittings. If the fittings are of welded construction, the tension specimen shall include the weld and shall be prepared so that the weld is at the midlength location of the specimen. However, in no case shall the tensile properties of the finished fitting be less than the requirements listed in the individual product specification.

NOTE S50.1—If the result of any of the tests specified in Supplementary Requirements S50, S51, or S63 do not conform to requirements, retests may be made at the manufacturer's expense on additional fittings or representative test pieces of double the original number from the same heat or lot as defined in Supplementary Requirements S50, S51, or S63, each of which shall conform to the requirements specified.

NOTE S50.2—Where the test specimen for the tension or intergranular corrosion bend test cannot be taken from a fitting due to size limitations, a representative test piece shall be obtained. The test piece shall be from the same lot it represents and shall have approximately the same amount of working. In addition, these pieces representing fittings manufactured from bars, plate, or forgings shall have a cross section equal to the greatest cross section of the fitting, and test pieces representing fittings manufactured from pipe shall have an outside diameter and wall thickness equal to those of the fitting. The test piece for fittings of welded construction shall be prepared to the same weld procedures and from the same heat of materials as the fittings it represents.

NOTE S50.3—A lot shall consist of all fittings of the same type, size, and wall thickness, manufactured from one heat of material (and, if fabrication welding is performed using one lot number of electrode or one heat of weld wire), and heat treated using the same heat-treat cycle in either a continuous or batch-tvpe furnace controlling within a range of 50 °F [28 °C] and equipped with recording pyrometers so that complete records of heat treatment are available.

S52. Liquid Penetrant Examination

S52.1 All surfaces shall be liquid penetrant examined in accordance with Test Method E 165. Acceptance limits shall be specified by the purchaser. Personnel performing the examination shall be qualified in accordance with SNT-TC-1A-1988 or later.

S53. Magnetic-Particle Examination

S53.1 All accessible surfaces shall be magnetic particle examined in accordance with Guide E 709. Acceptance limits shall be specified by the purchaser. Personnel performing the examination shall be qualified in accordance with SNT-TC-1A-1988 or later.

S54. Hydrostatic Test

S54.1 A hydrostatic test shall be applied as agreed upon between the manufacturer and purchaser.

S55. Bar Stock Fittings

S55.1 Bar stock fittings shall not be permitted.

S56. Special Heat Treatment

S56.1 A special heat treatment shall be applied as agreed upon between the manufacturer and the purchaser.

S57. Hardness Test

S57.1 If actual hardness testing of fittings is required, the frequency and the method used shall be as agreed upon between the manufacturer and the purchaser.

S58. Special Fittings

S58.1 Partial compliance fittings of size or shape not conforming to the dimensional requirements of ASME B16.9, B16.11, MSS-SP-79, and MSS-SP-95 shall meet all other requirements of the individual product specification. In addition to the marking required by Section 19, the grade designation symbol of the individual product specification shall be followed by the symbol "S58".

S59. Heat Treatment of Concentric Reducers

S59.1 Concentric reducers formed by local heating of the fitting shall be subsequently annealed, normalized, or normalized and tempered.

S60. Marking Small Fittings

S60.1 For small products where the space for marking is less than 1 in. [25 mm] in any direction, test reports are mandatory and marking may be restricted to only such symbols or codes as are necessary to identify the parts with test reports.

S60.2 When the configuration or size does not permit marking directly on the fitting, the marking method shall be a matter of agreement between the manufacturer and the purchaser.

S61. Phosphorous and Sulphur Content

S61.1 The phosphorous and sulphur contents of the fittings shall not exceed 0.025 %.

S62. Ultrasonic Test

S62.1 Each fitting or the raw material from which the fitting is made shall be ultrasonically tested to determine its soundness. The method, where applicable, shall be in accordance with Practice A 388/A 388M. Acceptance limits shall be specified by the purchaser. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A-1988 or later.

S62.2 Each fitting or the raw material from which each fitting is made shall be ultrasonically tested to determine its soundness. The method, where applicable, shall be in accordance with Practice E 213. Acceptable limits shall be specified by the purchaser. Personnel performing the examination shall be qualified in accordance with SNT-TC-1A-1988 or later.

S63. Intergranular Corrosion Bend Test (See Note S50.1)

S63.1 An intergranular corrosion bend test shall be made on one fitting or representative test piece (See Note S50.2) per lot (See Note S50.3) of fittings. If the fittings are of welded construction, the bend specimen shall include the weld and be prepared so that the weld is at the midlength location of the specimen. Specimens containing a weld shall be bent so that the location of weld is at the point of maximum bend. The method of testing shall be in accordance with Practices A 262 or Practices A 763, as applicable.

S64. Photomicrographs

S64.1 Photomicrographs at 100 diameters shall be made for information only of the actual base metal structure from one fitting as furnished in each lot. The photomicrographs shall be identified as to fitting size, wall thickness, lot identification, and heat. The definition of "lot" shall be as specified by the purchaser.

S65. Surface Finish

S65.1 Machined surfaces shall have a maximum roughness of 250 µin. AARH [6.3 µm]. All other surfaces shall be suitable for ultrasonic testing.

S66. Repair Welding

S66.1 No weld repair shall be permitted without prior approval of the purchaser.

S67. Charpy V-Notch Test

S67.1 Charpy V-notch test shall be made as specified on the order. The test temperature, acceptance criteria, number of tests, and location of tests (whether from base metal, weld metal, or heat affected zone of welds) shall be specified.

S68. Special Notch Toughness

S68.1 The impact test temperature or acceptance values, or both, shall be as agreed upon, but only with respect to lower temperatures or higher energy values.

S69. Magnetic Particle Examination—Weld Metal

S69.1 All accessible welds shall be examined in accordance with Guide E 709. Accessible is defined as all outside surfaces, all inside fitting surfaces 24 in. [610 mm] in diameter and greater, and inside fitting surfaces less than 24 in. [610 mm] in diameter, for a distance of one diameter from the ends.

S69.2 *Acceptance Criteria*—The following indications are unacceptable:

S69.2.1 Any cracks and linear indications, S69.2.2 Rounded indications with dimensions greater than 3⁄16 in. [4.8 mm],

S69.2.3 Four or more indications in any line separated by 1⁄16 in. [1.6 mm],

S69.2.4 Ten or more indications located in any 6 in.^{2}[4000 mm^2] of surface, with the major dimensions not to exceed 6 in. [150 mm] when the major dimension is oriented so that the area includes the maximum number of indications being evaluated.

S69.3 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A-1988 or later.

S70. Liquid Penetrant Examination of Weld Metal

S70.1 All accessible surfaces of fittings shall be examined in accordance with Test Method E 165. Accessible is defined in S69.

S70.2 Acceptance criteria shall be in accordance with S69.2.

S70.3 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A-1988 or later.

S71. Product Marking

S71.1 Weld repaired parts shall be marked "S71".

S72. Nondestructive Electromagnetic (Eddy-Current) Test

S72.1 For eddy-current testing, the calibration tube shall contain, at the option of the manufacturer, any one of the following discontinuities placed in the weld to establish a minimum sensitivity level for rejection.

S72.2 *Drilled Hole*—A hole not larger than 0.031 in. [0.79 mm] in diameter shall be drilled radially and completely through the tube wall, with care being taken to avoid distortion of the tube while drilling.

S72.3 *Transverse Tangential Notch*—Using a round tool or file with a ¼-in. [6-mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the tube. The notch shall have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. [0.102 mm], whichever is greater.

S72.4 *Longitudinal Notch*—A notch 0.031 in. [0.79 mm] or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. [0.102 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

S72.5 Fittings producing a signal equal to or greater than the calibration defect shall be subject to rejection. To be accepted, after rework, the fittings must pass the same test to which it was originally subjected.

S72.6 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A-1988 or later.

S73. Weld Metal Analysis

S73.1 Analysis of weld metal shall be reported.

S74. Welding Procedure Test Record

S74.1 A welding procedure test record shall be furnished.

S75. Chemical Analysis of Remelted Steel

S75.1 Each remelted ingot shall be assigned a unique identification number.

S75.2 A chemical analysis shall be made from each remelted ingot.

S76. Electropolished Austenitic Grades

S76.1 All electropolished austenitic fittings shall be of a cleanliness according to Specification A 967.

S76.2 Details concerning which test method of Specification A 967 are to be a matter of agreement between the manufacturer and the purchaser.

S77. Positive Material Identification Examination

S77.1 Fittings shall be examined to assure that the purchaser is receiving fittings of the correct material grade prior to shipment of the fittings. This examination is to assure that no material grade mix-up has happened during manufacturing and marking of the fittings.

S77.2 Fittings shall receive a Positive Material Identification examination using the methods of Guide E 1916.

S77.3 The quantity examined shall be 100 % of the fittings.

S77.4 All fittings that are not of the correct material grade shall be rejected.

S77.5 The method of fitting marking after this examination shall be agreed upon between the manufacturer and purchaser.

S78. Requirements for Carbon Steel Products for Concentrated Hydrofluoric Acid Service

S78.1 Products shall be provided in the normalized heat-treated condition.

S78.2 The maximum carbon equivalent based on heat analysis shall be as follows:

Maximum section thickness less than or equal to 1 in.	CE maximum = 0.43
Maximum section thickness greater than 1 in.	CE maximum = 0.45

S78.3 Determine the carbon equivalent (CE) as follows:

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

S78.4 Vanadium and Niobium maximum content based on heat analysis shall be:

Maximum Vanadium = 0.02 wt %

Maximum Niobium = 0.02 wt %

Maximum Vanadium plus Niobium = 0.03 wt %

(Note Niobium = Columbium)

S78.5 The maximum composition based on heat analysis of Ni + Cu shall be 0.15 wt %.

S78.6 The minimum C content based on heat analysis shall be 0.18 wt %. The maximum C content shall be as specified in the appropriate material specification.

S78.7 Repair welds shall not be made with E60XX electrodes. Use of E70XX electrodes is recommended and the resulting weld chemistry should meet the same chemistry criteria as the base metal as listed above.

S78.8 In addition to the requirements of product marking of the specification, an ″HF-N″ stamp or marking shall be provided on each component to identify that component complies with this supplementary requirement.

S79 Pressure Equipment Directive—Mechanical Testing

S79.1 Charpy impact testing shall be done at the lowest scheduled operating temperature, but not higher than 68 °F [20 °C].

S79.2 The frequency of impact testing shall be the same as that specified in the product specification for the tension test, with three individual Charpy test specimens for each required tension test.

S79.3 The minimum impact absorption energy for the Charpy test specimen shall be at least 20 ft-lb [27 J].

S79.4 The minimum elongation in the tension test shall be measured on a gage length of five times the diameter of the test specimen, and shall not be less than 14 %.

S79.5 Impact and tension test results shall be included in the product certification.

ANNEX

(Mandatory Information)

A1. Requirements for the Introduction of New Materials

A1.1 New materials may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A1.1.1 Application for the addition of a new grade to a specification shall be made to the chairman of the subcommittee, which has jurisdiction over that specification.

A1.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable specification.

A1.1.3 The application shall be accompanied by test data as required by the applicable specification. Test data from a minimum of three test lots, as defined by the specification, each from a different heat, shall be furnished.

A1.1.4 The application shall provide recommendations for all requirements appearing in the applicable specification.

A1.1.5 The application shall state whether the new grade is covered by patent.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 960/A 960M – 06, that may impact the use of this specification. (Approved February 1, 2007)

(*1*) Deleted the term "ASTM" in 19.1 and 20.1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 960/A 960M – 04a, that may impact the use of this specification. (Approved March 1, 2006)

(*1*) Added new paragraph 8.2.1 on grade substitution.

Designation: A 949/A 949M – 01 (Reapproved 2005)

Standard Specification for Spray-Formed Seamless Ferritic/Austenitic Stainless Steel Pipe[1]

This standard is issued under the fixed designation A 949/A 949M; 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 covers spray-formed seamless ferritic/austenitic stainless steel pipe intended for general corrosive service, with particular emphasis on resistance to stress corrosion cracking. These steels are susceptible to embrittlement if used for prolonged periods at elevated temperatures.

1.2 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and when desired, one or more of these may be specified in the order.

1.3 Appendix X1 of this specification lists the dimensions of seamless stainless steel pipe as shown in ANSI B 36.19. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

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 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:* [2]

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe
E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *ANSI/ASME Standards:*

B 1.20.1 Pipe Threads, General Purpose[3]
B 36.10M-1995 Welded and Seamless Wrought Steel Pipe[3]
B 36.19 Stainless Steel Pipe

2.3 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[4]

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms used in this specification, refer to Terminology A 941.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *spray-formed*—denotes the fabrication of different shapes of a metallic material by deposition of a spray, consisting of droplets, solid particles, and particles that are partially solid, onto a moving substrate.

3.2.1.1 *Discussion*—The spray is produced by gas atomization of the liquid metal or alloy. On impingement with the substrate, the species of the spray consolidate and solidify completely to produce a product that is essentially free of porosity. The metallurgical characteristics of the spray-formed product are controlled primarily by the thermal condition of the spray, and that of the surface of the metallic deposit formed on the substrate.

4. Ordering Information

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

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (ferritic/austenitic steel pipe),

4.1.3 Grade (Table 1),

4.1.4 Size (NPS designator or outside diameter and schedule number of average wall thickness, or other),

[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.

Current edition approved Sept. 1, 2005. Published October 2005. Originally approved in 1995. Last previous edition approved in 2001 as A 949/A 949M – 01.

[2] 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.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

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

TABLE 1 Heat Treatment

UNS Designation	Temperature	Quench
S31803	1870–2010°F [1020–1100°C]	rapid cooling in air or water
S31500	1800–1900°F [980–1040°C]	rapid cooling in air or water
S31200	1920–2010°F [1050–1100°C]	rapid cooling in water
S32550	1900°F [1040°C] min	rapid cooling in air or water
S31260	1870–2010°F [1020–1100°C]	rapid cooling in water
S32304	1700–1920°F [925–1050°C]	rapid cooling in air or water
S32750	1880–2060°F [1025–1125°C]	rapid cooling in air or water
S32900	1700–1750°F [925–955°C]	rapid cooling in air or water
S32950	1820–1880°F [995–1025°C]	air cool

4.1.5 Length (specific or random) (Section 10),

4.1.6 End finish (section on Ends of Specification A 999/A 999M),

4.1.7 Optional requirements (Section 9), Supplementary Requirements S1 to S4,

4.1.8 Test report required (section on Certification of Specification A 999/A 999M),

4.1.9 Specification designation, and

4.1.10 Special requirements or exceptions to the specification.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

6. Materials and Manufacture

6.1 *Melting*—The steel shall be made by the electric-furnace process or other primary processes approved by the purchaser.

6.2 *Pipe Manufacture*:

6.2.1 The pipe shall be made by the spray forming process using the melt from the primary melting as noted in 7.1.

6.2.2 The pipe shall be made by spraying the melt on to a thin-walled collector tube. The as spray formed tube shall be machined on both the inner and outer surfaces. The remaining metal shall be homogeneous, sound, and meet the requirements of Section 11.

6.2.3 Unless specified by the purchaser, pipe may be furnished as spray formed or as spray-formed and cold-finished.

6.2.4 All pipe shall be furnished in the heat-treated condition as shown in Table 1.

6.2.5 All pipe shall be furnished in the descaled condition and be free of contaminating iron particles. Pickling, blasting or surface finishing is not mandatory when pipe is bright annealed. The purchaser may request that a passivating treatment be applied.

7. Chemical Composition

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

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 of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of stainless steel:

NPS Designator	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5, incl	200 or fraction thereof
6 and over	100 or fraction thereof

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 Section 5.

8.3 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in Section 5, an analysis of each pipe from the same heat or lot may be made, and all pipes conforming to the requirements shall be accepted.

9. Tensile and Hardness Properties

9.1 The material shall conform to the tensile and hardness properties prescribed in Table 3.

10. Lengths

10.1 Pipe lengths shall be in accordance with the following regular practice:

10.1.1 Unless otherwise agreed upon, all sizes from NPS ⅛ to and including NPS 8 are available in a length up to 24 ft (Note 2) with the permissible range of 15 to 24 ft (Note 2). Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

NOTE 2—This value 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 the purchaser.

10.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be less than the specified length and no more than ¼ in. [6 mm] over it.

TABLE 2 Chemical Requirements

UNS Designation[A]	C	Mn	P	S	Si	Ni	Cr	Mo	N	Cu	Others
S31803	0.030 max	2.00 max	0.030 max	0.020 max	1.00 max	4.5–6.5	21.0–23.0	2.5–3.5	0.08–0.20	. . .	
S31500	0.030 max	1.20–2.00	0.030 max	0.030 max	1.40–2.00	4.3–5.2	18.0–19.0	2.50–3.00	0.05–0.10	. . .	
S32550	0.040 max	1.50 max	0.040 max	0.030 max	1.00 max	4.5–6.5	24.0–27.0	2.9–3.9	0.10–0.25	1.50–2.50	
S31200	0.030 max	2.00 max	0.045 max	0.030 max	1.00 max	5.5–6.5	24.0–26.0	1.20–2.00	0.14–0.20	. . .	
S31260	0.030 max	1.00 max	0.030 max	0.030 max	0.75 max	5.5–7.5	24.0–26.0	2.5–3.5	0.10–0.30	0.20–0.80	W 0.10–0.50
S32304	0.030 max	2.50 max	0.040 max	0.040 max	1.00 max	3.0–5.5	21.5–24.5	0.05–0.60	0.05–0.20	0.05–0.60	
S32750	0.030 max	1.20 max	0.035 max	0.020 max	0.80 max	6.0–8.0	24.0–26.0	3.0–5.0	0.24–0.32	0.50 max	. . .
S32900	0.08 max	1.00 max	0.040 max	0.030 max	0.75 max	2.5–5.0	23.0–28.0	1.00–2.00	. . .	. . .	. . .
S32950	0.03 max	2.00 max	0.035 max	0.010 max	0.60 max	3.5–5.2	26.0–29.0	1.00–2.50	0.15–0.35	. . .	

[A] New designation established in accordance with Practice E 527 and SAE J1086.

TABLE 3 Tensile and Hardness Requirements

UNS Designation	Tensile Strength min, ksi [MPa]	Yield Strength min, ksi [MPa]	Elongation in 2 in. or [50 mm] min,%	Hardness, max	
				Brinell	Rockwell C
S31803	90 [620]	65 [450]	25	290	30.5
S31500	92 [635]	64 [440]	30	290	30.5
S31200	110 [760]	80 [550]	15	297	31.5
S32550	100 [690]	65 [450]	25	280	. . .
S31260	100 [690]	65 [450]	25	. . .	. . .
S32304	87 [600]	58 [400]	25	290	30.5
S32750	116 [800]	80 [550]	15	310	32
S32900	90 [620]	70 [485]	20	271	28
S32950	90 [620]	70 [485]	20	290	30.5

11. Workmanship, Finish, and Appearance

11.1 The finished pipes shall be reasonably straight and shall have a workmanlike finish. Imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted, in the Permissible Variations in Wall Thickness Section of Specification A 999/A 999M.

12. Mechanical Tests Required

12.1 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two pipes for lots of more than 100 pipes.

NOTE 3—The term "lot," for mechanical tests, 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: (*1*) in a continuous heat-treatment furnace, or (*2*) in a batch-type heat-treatment furnace, equipped with recording pyrometers and automatically controlled within a 50°F [30°C] range, the larger of: (*a*) each 200 ft [60 m] or fraction thereof or, (*b*) that pipe heat treated in the same batch furnace charge.

12.2 *Flattening Test*—For material heat treated in a batch-type furnace, flattening tests shall be made on 5 % of the pipe from each heat-treated lot. For material heat treated by the continuous process, this test shall be made on a sufficient number of pipes to constitute 5 % of the lot, but in no case less than two lengths of pipe.

12.3 *Hydrostatic Test*—Each length of finished pipe shall be subjected to the hydrostatic test.

12.3.1 The hydrostatic test shall be in accordance with Specification A 999/A 999M. When making the calculations in the Hydrostatic Test Requirements Section of Specification A 999/A 999M, an *S* value 50 % of the specified minimum yield strength shall be used.

12.3.2 When specified by the purchaser, a nondestructive electric test in accordance with Specification A 450/A 450M may be used instead of, or in addition to, the hydrostatic test.

13. Product Marking

13.1 In addition to the marking specified in Specification A 999/A 999M, all marking shall include the manufacturer's private identifying mark and be given the designator, CF, when cold finished. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

14. Keywords

14.1 austenitic/ferritic; pipe; spray-formed; stainless

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe over NPS 5 there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 5 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This applies only to pipe over NPS 8.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

APPENDIX

(Nonmandatory Information)

X1. Table X1.1 IS BASED ON TABLE 1 OF THE AMERICAN NATIONAL STANDARD FOR STAINLESS STEEL PIPE (ANSI/ASME B36.19M-1985)

TABLE X1.1 Dimensions of Welded and Seamless Stainless Steel Pipe

NOTE 1—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[A]		Schedule 10S[A]		Schedule 40S		Schedule 80S	
			in.	mm	in.	mm	in.	mm	in.	mm
⅛	0.405	[10.29]	. . .	. . .	0.049[B]	[1.24]	0.068	[1.73]	0.095	[2.41]
¼	0.540	[13.72]	. . .	. . .	0.065[B]	[1.65]	0.088	[2.24]	0.119	[3.02]
⅜	0.675	[17.15]	. . .	. . .	0.065[B]	[1.65]	0.091	[2.31]	0.126	[3.20]
½	0.840	[21.34]	0.065[B]	[1.65]	0.083[B]	[2.11]	0.109	[2.77]	0.147	[3.73]
¾	1.050	[26.67]	0.065[B]	[1.65]	0.083[B]	[2.11]	0.113	[2.87]	0.154	[3.91]
1.0	1.315	[33.40]	0.065[B]	[1.65]	0.109[B]	[2.77]	0.133	[3.38]	0.179	[4.55]
1¼	1.660	[42.16]	0.065[B]	[1.65]	0.109[B]	[2.77]	0.140	[3.56]	0.191	[4.85]
1½	1.900	[48.26]	0.065[B]	[1.65]	0.109[B]	[2.77]	0.145	[3.68]	0.200	[5.08]
2	2.375	[60.33]	0.065[B]	[1.65]	0.109[B]	[2.77]	0.154	[3.91]	0.218	[5.54]
2½	2.875	[73.03]	0.083	[2.11]	0.120[B]	[3.05]	0.203	[5.16]	0.276	[7.01]
3	3.500	[88.90]	0.083	[2.11]	0.120[B]	[3.05]	0.216	[5.49]	0.300	[7.62]
3½	4.000	[101.60]	0.083	[2.11]	0.120[B]	[3.05]	0.226	[5.74]	0.318	[8.08]
4	4.500	[114.30]	0.083	[2.11]	0.120[B]	[3.05]	0.237	[6.02]	0.337	[8.56]
5	5.563	[141.30]	0.109[B]	[2.77]	0.134[B]	[3.40]	0.258	[6.55]	0.375	[9.52]
6	6.625	[168.28]	0.109	[2.77]	0.134[B]	[3.40]	0.280	[7.11]	0.432	[10.97]
8	8.625	[219.08]	0.109[B]	[2.77]	0.148[B]	[3.76]	0.322	[8.18]	0.500	[12.70]
10	10.750	[273.05]	0.134[B]	[3.40]	0.165[B]	[4.19]	0.365	[9.27]	0.500[B]	[12.70][B]
12	12.750	[323.85]	0.156[B]	[3.96]	0.180[B]	[4.57]	0.375[B]	[9.52][B]	0.500[B]	[12.70][B]
14	14.000	[355.60]	0.156[B]	[3.96]	0.188	[4.78]	. . .	. . .	. . .	. . .
16	16.000	[406.40]	0.165[B]	[4.19]	0.188	[4.78]	. . .	. . .	. . .	. . .
18	18.000	[457.20]	0.165[B]	[4.19]	0.188	[4.78]	. . .	. . .	. . .	. . .
20	20.000	[508.00]	0.188[B]	[4.78]	0.218[B]	[5.54]	. . .	. . .	. . .	. . .
22	22.000	[558.80]	0.188[B]	[4.78]	0.218[B]	[5.54]	. . .	. . .	. . .	. . .
24	24.000	[609.60]	0.218[B]	[5.54]	0.250	[6.35]	. . .	. . .	. . .	. . .
30	30.000	[762.00]	0.250	[6.35]	0.312	[7.92]	. . .	. . .	. . .	. . .

[A] Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI/ASME B 1.20.1).
[B] These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI/ASME B 36.10M-1995).

Designation: A 943/A 943M – 01 (Reapproved 2005)

Standard Specification for Spray-Formed Seamless Austenitic Stainless Steel Pipes[1]

This standard is issued under the fixed designation A 943/A 943M; 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 covers spray-formed seamless austenitic stainless steel pipe intended for high-temperature and general corrosive service.

1.2 Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP309Cb, TP309S, TP310Cb, TP310S, TP316, TP321, TP347, and TP348, and are intended for high-temperature service.

1.3 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.4 Appendix X1 lists the dimensions of seamless stainless steel pipe as shown in ANSI B36.19. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.5 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 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:* [2]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

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

E 112 Test Methods for Determining Average Grain Size

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

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *ANSI/ASME Standards:*[3]

B1.20.1 Pipe Threads, General Purpose

B36.10 Welded and Seamless Wrought Steel Pipe

B36.19 Stainless Steel Pipe

2.3 *Other Standard:*[4]

SAE J1086 Practice for Numbering Metals and Alloys (UNS)

3. Terminology

3.1 For definitions of terms used in this specification, refer to Terminology A 941.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *spray–formed*—denotes the fabrication of different shapes of a metallic material by deposition of a spray, consisting of droplets, solid particles, and particles that are partially solid, onto a moving substrate.

3.2.1.1 *Discussion*—The spray is produced by gas atomization of the liquid metal or alloy. On impingement with the substrate, the species of the spray consolidate and solidify completely to produce a product that is essentially free of porosity. The metallurgical characteristics of the spray-formed product are controlled primarily by the thermal condition of the spray, and that of the surface of the metallic deposit formed on the substrate.

4. Ordering Information

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

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

[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 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.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

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

4.1.2 Name of material (austenitic steel pipe),

4.1.3 Grade (Table 1),

4.1.4 Size (NPS or outside diameter and schedule number or average wall thickness or other),

4.1.5 Length (specific or random) (Section 11),

4.1.6 End finish (Section on Ends of Specification A 999/A 999M),

4.1.7 Optional requirements (Section 8),

4.1.8 Test report required (Certification Section of Specification A 999/A 999M),

TABLE 1 Chemical Requirements

Grade	UNS Designation[A]	Composition, %									Columbium plus Tantalum	Composition, %				
		Carbon, max[B]	Manganese, max[B]	Phosphorus, max	Sulfur, max	Silicon, max[B]	Nickel	Chromium	Molybdenum	Titanium		Tantalum, max	Nitrogen[C]	Vanadium	Copper	Cerium
TP304	S30400	0.08	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP304L	S30403	0.030	2.00	0.045	0.030	0.75	8.0–13.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP304N	S30451	0.08	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .
TP304LN	S30453	0.030	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .
TP309Cb	S30940	0.08	2.00	0.045	0.030	0.75	12.0–16.0	22.0–24.0	0.75 max	. . .	10 × C min 1.10 max	. . .	. . .	. . .	. . .	. . .
TP309H	S30909	0.04–0.10	2.00	0.045	0.030	0.75	12.0–15.0	22.0–24.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP309HCb	S30941	0.04–0.10	2.00	0.045	0.030	0.75	12.0–16.0	22.0–24.0	0.75 max	. . .	10 × C min 1.10 max	. . .	. . .	. . .	. . .	. . .
TP309S	S30908	0.08	2.00	0.045	0.030	0.75	12.0–15.0	22.0–24.0	0.75 max	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP310Cb	S31040	0.08	2.00	0.045	0.030	0.75	19.0–22.0	24.0–26.0	0.75 max	. . .	10 × C min 1.10 max	. . .	. . .	. . .	. . .	. . .
TP310H	S31009	0.04–0.10	2.00	0.045	0.030	0.75	19.0–22.0	24.0–26.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP310HCb	S31041	0.04–0.10	2.00	0.045	0.030	0.75	19.0–22.0	24.0–26.0	0.75 max	. . .	10 × C min 1.10 max	. . .	. . .	. . .	. . .	. . .
TP310S	S31008	0.08	2.00	0.045	0.030	0.75	19.0–22.0	24.0–26.0	0.75 max	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S31272[D]	0.08–0.12	1.50–2.00	0.030	0.015	0.3–0.7	14.0–16.0	14.0–16.0	1.00–1.0	0.3–0.6	. . .	. . .	. . .	. . .	. . .	. . .
TP316	S31600	0.08	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP316L	S31603	0.030	2.00	0.045	0.030	0.75	10.0–15.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP316N	S31651	0.08	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .
TP316LN	S31653	0.030	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .
TP317	S31700	0.08	2.00	0.045	0.030	0.75	11.0–14.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP317L	S31703	0.030	2.00	0.045	0.030	0.75	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP321	S32100	0.08	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	. . .	[E]	. . .	. . .	. . .	. . .	. . .	. . .
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	. . .	[F]	. . .	. . .	. . .	. . .	. . .	. . .
TP347	S34700	0.08	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	. . .	. . .	[G]	. . .	. . .	. . .	. . .	. . .
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	. . .	. . .	[H]	. . .	. . .	. . .	. . .	. . .
TP348	S34800	0.08	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	. . .	. . .	[G]	0.10	. . .	. . .	. . .	. . .
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	. . .	. . .	[H]	0.10	. . .	. . .	. . .	. . .
TPXM-10	S21900	0.08	8.0–10.0	0.045	0.030	1.00	5.5–7.5	19.0–21.5	. . .	. . .	. . .	. . .	0.15–0.40	. . .	. . .	. . .
TPXM-11	S21903	0.04	8.0–10.0	0.045	0.030	1.00	5.50–7.5	19.0–21.5	. . .	. . .	. . .	. . .	0.15–0.40	. . .	. . .	. . .
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.5–18.5	17.0–19.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TPXM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	11.5–13.5	20.5–23.5	1.50–3.00	. . .	0.10–0.30	. . .	0.20–0.40	0.10–0.30	. . .	. . .
TPXM-29	S24000	0.08	11.5–14.5	0.060	0.030	1.00	2.2–3.7	17.0–19.0	. . .	. . .	. . .	. . .	0.20–0.40	. . .	. . .	. . .
. . .	S31254	0.020	1.00	0.030	0.010	0.80	17.5–18.5	19.5–20.5	6.0–6.5	. . .	. . .	. . .	0.18–0.22	. . .	0.50–1.00	. . .
. . .	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	. . .	. . .	. . .	. . .	0.14–0.20	. . .	. . .	0.03–0.08
. . .	S31050	0.030	2.00	0.020	0.015	0.4	20.5–23.5	24.0–26.0	1.0–2.0	. . .	. . .	. . .	0.09–0.15	. . .	. . .	. . .
. . .	S30600	0.018	2.00	0.02	0.02	3.7–4.3	14.0–15.5	17.0–18.5	0.20 max	. . .	. . .	. . .	. . .	. . .	0.50 max	. . .
. . .	S31725	0.030	2.00	0.045	0.030	0.75	13.5–17.5	18.0–20.0	4.0–5.0	. . .	. . .	. . .	0.10 max	. . .	0.75 max	. . .
. . .	S31726	0.030	2.00	0.045	0.030	0.75	13.5–17.5	17.0–20.0	4.0–5.0	. . .	. . .	. . .	0.10–0.20	. . .	0.75 max	. . .
. . .	S32615	0.07	2.00	0.045	0.030	4.8–6.0	19.0–22.0	16.5–19.5	0.30–1.50	. . .	. . .	. . .	. . .	. . .	1.50–2.50	. . .
. . .	S34565	0.030	5.0–7.0	0.030	0.010	1.00	16.0–18.0	23.0–25.0	4.0–5.0	. . .	0.1 max	. . .	0.40–0.60	. . .	. . .	. . .

[A] New designation established in accordance with Practice E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

[B] Maximum, unless otherwise indicated.

[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

[D] The boron content shall be in the range 0.004–0.008.

[E] The titanium content shall be not less than five times the carbon content and not more than 0.70 %.

[F] The titanium content shall be not less than four times the carbon content and not more than 0.60 %.

[G] The columbium (niobium) plus tantalum content shall be not less than ten times the carbon content and not more than 1.00 %.

[H] The columbium (niobium) plus tantalum content shall be not less than eight times the carbon content and not more than 1.0 %.

4.1.9 Specification number, and

4.1.10 Special requirements or any supplementary requirements selected, or both.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

6. Materials and Manufacture

6.1 *Melting*—The steel shall be made by the electric-furnace process or by other similar processes. The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, using electroslag remelting or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

6.1.1 If a specified type of melting is required by the purchaser, it shall be stated on the purchase order.

6.1.2 When specified on the purchase order, or when a specific type of melting has been specified, the material manufacturer shall include with the report required by the Heat Analysis section of this specification or the Certification section of Specification A 999/A 999M the type of melting used to produce the material.

6.2 *Pipe Manufacture*:

6.2.1 The pipe shall be made by the spray forming process using the steel from the electric steel process or other similar processes as in 6.1.

6.2.2 The pipe shall be made by spraying the melt on to a thin-walled collector tube. The as-spray formed pipe shall be machined on both the inner and outer surfaces. The remaining metal shall be homogeneous, sound, and meet the requirements of Section 11.

6.2.3 Unless specified by the purchaser, pipe may be furnished as-spray formed or as-spray formed and cold finished.

6.2.4 All pipe shall be furnished in the descaled condition and be free of contaminating iron particles. Pickling, blasting or surface finishing is not mandatory when pipe is bright annealed. The purchaser may request that a passivating treatment be applied.

6.3 *Heat Treatment*:

6.3.1 All pipe shall be furnished in the heat-treated condition. The heat-treatment procedure, except for "H" grades, S30815 and S31254, shall consist of heating the pipe to a minimum temperature of 1900°F [1040°C] and quenching in water or rapidly cooling by other means.

6.3.2 All H grades shall be furnished in the solution-treated condition. If cold working is involved in processing, the minimum solution treating temperature for Grades TP321H, TP347H, and TP348H shall be 2000°F [1100°C] and for Grades TP304H, and TP316H, 1900°F [1040°C]. If the H Grade is furnished in the spray-formed condition only, the minimum solution treating temperatures for Grades TP321H, TP347H, and TP348H shall be 1925°F [1050°C], and for Grades TP304H, and TP316H, 1900°F [1040°C]. The minimum solution treating temperature for S30815 shall be 1920°F [1050°C]. The minimum solution treating temperature for TP309H, TP309HCb, TP310H, and TP310HCb shall be 1900°F [1040°C].

6.3.3 The heat-treatment procedure for S31254 shall consist of heating the pipe to a minimum temperature of 2100°F [1150°C] and quenching in water or rapidly cooling by other means.

6.3.4 A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S6).

6.4 *Grain Size*:

6.4.1 The grain size of TP304H, TP316H, TP321H, TP347H and TP348H, as determined in accordance with Test Methods E 112, shall be ASTM No. 7 or coarser.

6.4.2 The grain size of TP309H, TP309HCb, TP310H and TP310HCb, shall be ASTM No. 6 or coarser.

7. Chemical Composition

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

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 of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of stainless steel:

NPS Designator	Lengths of Pipe in Lot
Under 2	
2 to 5	200 or fraction thereof
6 and over	100 or fraction thereof

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 Section 7.

8.3 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in Section 7, an analysis of each pipe from the same heat or lot may be made, and all pipes conforming to the requirements shall be accepted.

9. Tensile Requirements

9.1 The tensile properties of the material shall conform to the requirements prescribed in Table 2.

10. Mechanical Tests and Grain Size Determinations Required

10.1 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes.

NOTE 2—The term "lot," for mechanical tests, applies to all pipe of the same diameter and wall thickness (or schedule) that are produced from the same heat of steel and subjected to the same finishing treatment: (*1*) in a continuous heat treatment furnace, or (*2*) in a batch-type heat treatment furnace, equipped with recording pyrometers and automatically controlled

TABLE 2 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
TP304L	S30403	70 [485]	25 [170]
TP316L	S31603	70 [485]	25 [170]
TP304	S30400	75 [515]	30 [205]
TP304H	S30409	75 [515]	30 [205]
TP309Cb	S30940	75 [515]	30 [205]
TP309H	S30909	75 [515]	30 [205]
TP309HCb	S30941	75 [515]	30 [205]
TP309S	S30908	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310H	S31009	75 [515]	30 [205]
TP310HCb	S31041	75 [515]	30 [205]
TP310S	S31008	75 [515]	30 [205]
. . .	S31272	65 [450]	29 [200]
TP316	S31600	75 [515]	30 [205]
TP316H	S31609	75 [515]	30 [205]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
TP321	S32100:		
t[A] ≤ ⅜ in.		75 [515]	30 [205]
t > ⅜ in.		70 [485]	25 [170]
TP321H	S32109:		
t ≤ ⅜ in.		75 [515]	30 [205]
t > ⅜ in.		70 [485]	25 [170]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21903	90 [620]	50 [345]
TPXM-15	S38100	75 [515]	30 [205]
TPXM-29	S24000	100 [690]	55 [380]
TPXM-19	S20910	100 [690]	55 [380]
TP304N	S30451	80 [550]	35 [240]
TP316N	S31651	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
TP316LN	S31653	75 [515]	30 [205]
. . .	S31254	94 [650]	44 [300]
. . .	S30815	87 [600]	45 [310]
. . .	S30600	78 [540]	35 [240]
. . .	S31725	75 [515]	30 [205]
. . .	S31726	80 [550]	35 [240]
. . .	S31050		
t ≤ 0.25 in.		84 [580]	39 [270]
t > 0.25 in.		78 [540]	37 [255]
. . .	S32615	80 [550]	32 [220]
. . .	S34565	115 [795]	60 [415]
Elongation in 2 in. or 50 mm (or 4D), min, %:		Longitudinal	Transverse
All Grades except S31050 and S32615		35	25
S31050 and S32615		25	. . .

[A] t = Specified wall thickness.

within a 50°F [30°C] range, the larger of: (*a*) each 200 ft [60°C] or fraction thereof or (*b*) that pipe heat treated in the same batch furnace charge.

10.2 *Flattening Test*—For material heat treated in a batch-typed furnace, flattening tests shall be made on 5 % of the pipe from each heat-treated lot. For material heat treated by the continuous process, this test shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than two lengths of pipe.

10.3 *Hydrostatic Test*:

10.3.1 Each length of finished pipe shall be subjected to the hydrostatic test in accordance with Specification A 999/A 999M, unless specifically exempted under the provisions of 10.3.2.

10.3.2 For pipe whose dimensions are equal to or exceed NPS 10, the purchaser with the agreement of the manufacturer may waive the hydrostatic test requirement when in lieu of such test the purchaser performs a system test. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory markings the letters "NH".

10.3.3 When specified by the purchaser, a non-destructive electric test in accordance with Specification A 450/A 450M may be used instead of, or in addition to, the hydrostatic test.

10.4 *Grain Size*—Grain size determination, when required, shall be made on the same number of tubes as prescribed in 10.2.

11. Lengths

11.1 Pipe lengths shall be in accordance with the following regular practice:

11.1.1 Unless otherwise agreed upon, all sizes from NPS ⅛ to and including NPS 8 are available in a length up to 24 ft (Note 3) with the permissible range of 15 to 24 ft (Note 3). Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

NOTE 3—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 the purchaser.

11.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and not more than ¼ in. [6 mm] over that specified.

12. Workmanship, Finish, and Appearance

12.1 The finished pipes shall be reasonably straight and shall have a workmanlike finish. Imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted, in Section 8 of Specification A 999/A 999M.

13. Product Marking

13.1 In addition to the marking specified in Specification A 999/A 999M, the marking shall include the manufacturer's private identifying mark and the marking requirement of 10.3.2, if applicable. The marking shall also include a designator, CF, when cold finishing is performed. For Grades TP304H, TP316H, TP321H, TP347H, TP348H, and S30815, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

14. Keywords

14.1 austenitic; pipe; spray-formed; stainless

SUPPLEMENTARY REQUIREMENTS

FOR PIPE REQUIRING SPECIAL CONSIDERATION

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe NPS 5 and larger in nominal size there shall be one product analysis made of a representative sample from one piece of each ten lengths or fraction hereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 7 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This applies only to pipe NPS 8 and larger.

S2.2 If a specimen from any length fails to conform to the tensile properties specified, that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Stabilizing Heat Treatment

S5.1 Subsequent to the solution anneal required in 6.3.4, Grades TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S6. Intergranular Corrosion Test

S6.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S6.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S6.2 A stabilization heat treatment in accordance with Supplementary Requirement S5 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

S7. Minimum Wall Pipe

S7.1 When specified by the purchaser, pipe shall be furnished on a minimum wall basis. The wall of such pipe shall not fall below the thickness specified. In addition to the marking required by Section 13, the pipe shall be marked S7.

APPENDIX

(Nonmandatory Information)

X1. Welded and Seamless Stainless Steel Pipe Dimensions

X1.1 Table X1.1 is based on Table 1 of the American National Standard for Stainless Steel Pipe (ANSI/ASME B36.19M–1985).

TABLE X1.1 Dimensions of Welded and Seamless Stainless Steel Pipe

NOTE 1—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[A]		Schedule 10S[A]		Schedule 40S		Schedule 80S	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
⅛	0.405	[10.29]	. . .	. . .	0.049	[1.24]	0.068	[1.73]	0.095	[2.41]
¼	0.540	[13.72]	. . .	. . .	0.065	[1.65]	0.088	[2.24]	0.119	[3.02]
⅜	0.675	[17.15]	. . .	. . .	0.065	[1.65]	0.091	[2.31]	0.126	[3.20]
½	0.840	[21.34]	0.065	[1.65]	0.083	[2.11]	0.109	[2.77]	0.147	[3.73]
¾	1.050	[26.67]	0.065	[1.65]	0.083	[2.11]	0.113	[2.87]	0.154	[3.91]
1.0	1.315	[33.40]	0.065	[1.65]	0.109	[2.77]	0.133	[3.38]	0.179	[4.55]
1¼	1.660	[42.16]	0.065	[1.65]	0.109	[2.77]	0.140	[3.56]	0.191	[4.85]
1½	1.900	[48.26]	0.065	[1.65]	0.109	[2.77]	0.145	[3.68]	0.200	[5.08]
2	2.375	[60.33]	0.065	[1.65]	0.109	[2.77]	0.154	[3.91]	0.218	[5.54]
2½	2.875	[73.03]	0.083	[2.11]	0.120	[3.05]	0.203	[5.16]	0.276	[7.01]
3	3.500	[88.90]	0.083	[2.11]	0.120	[3.05]	0.216	[5.49]	0.300	[7.62]
3½	4.000	[101.60]	0.083	[2.11]	0.120	[3.05]	0.226	[5.74]	0.318	[8.08]
4	4.500	[114.30]	0.083	[2.11]	0.120	[3.05]	0.237	[6.02]	0.337	[8.56]
5	5.563	[141.30]	0.109	[2.77]	0.134	[3.40]	0.258	[6.55]	0.375	[9.52]
6	6.625	[168.28]	0.109	[2.77]	0.134	[3.40]	0.280	[7.11]	0.432	[10.97]
8	8.625	[219.08]	0.109	[2.77]	0.148	[3.76]	0.322	[8.18]	0.500	[12.70]
10	10.750	[273.05]	0.134	[3.40]	0.165	[4.19]	0.365	[9.27]	0.500[B]	[12.70][B]
12	12.750	[323.85]	0.156	[3.96]	0.180	[4.57]	0.375[B]	[9.52][B]	0.500[B]	[12.70][B]
14	14.000	[355.60]	0.156	[3.96]	0.188[B]	[4.78][B]	. . .	. . .	. . .	. . .
16	16.000	[406.40]	0.165	[4.19]	0.188[B]	[4.78][B]	. . .	. . .	. . .	. . .
18	18.000	[457.20]	0.165	[4.19]	0.188[B]	[4.78][B]	. . .	. . .	. . .	. . .
20	20.000	[508.00]	0.188	[4.78]	0.218[B]	[5.54][B]	. . .	. . .	. . .	. . .
22	22.000	[558.80]	0.188	[4.78]	0.218[B]	[5.54][B]	. . .	. . .	. . .	. . .
24	24.000	[609.60]	0.218	[5.54]	0.250	[6.35]	. . .	. . .	. . .	. . .
30	30.000	[762.00]	0.250	[6.35]	0.312	[7.92]	. . .	. . .	. . .	. . .

[A] Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI/ASME B1.20.1).
[B] These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI/ASME B36.10M-1985).

Designation: A 941 – 06a

Standard Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys[1]

This standard is issued under the fixed designation A 941; 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 standard is a compilation of definitions of terms related to steel, stainless steel, related alloys, and ferroalloys.

1.2 When a term is used in an ASTM document for which Committee A01 is responsible, it is included herein only when judged, after review by Subcommittee A01.92, to be a generally usable term.

1.3 Some definitions include a discussion section, which is a mandatory part of the definition and contains additional information that is relevant to the meaning of the defined term.

1.4 Definitions of terms specific to a particular standard will appear in that standard and will supersede any definitions of identical terms in this standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 112 Test Methods for Determining Average Grain Size

3. Terminology

3.1 *Definitions of General Terms:*

alloy steel, *n*—a **steel**, other than a **stainless steel**, that conforms to a specification that requires one or more of the following elements, by mass percent, to have a minimum content equal to or greater than: 0.30 for aluminum; 0.0008 for boron; 0.30 for chromium; 0.30 for cobalt; 0.40 for copper; 0.40 for lead; 1.65 for manganese; 0.08 for molybdenum; 0.30 for nickel; 0.06 for niobium (columbium); 0.60 for silicon; 0.05 for titanium; 0.30 for tungsten (wolfram); 0.10 for vanadium; 0.05 for zirconium; or 0.10 for any other alloying element, except sulphur, phosphorus, carbon, and nitrogen.

capped steel, *n*—a **rimmed steel** in which, during ingot solidification, the rimming action was limited by mechanical or chemical means.

carbon steel, *n*—a **steel** that conforms to a specification that prescribes a maximum limit, by **heat analysis** in mass percent, of not more than: 2.00 for carbon and 1.65 for manganese, but does not prescribe a minimum limit for chromium, cobalt, molybdenum, nickel, niobium (columbium), tungsten (wolfram), vanadium, or zirconium.

Discussion—Except as required above, it is permissible for carbon steel specifications to prescribe limits (minimum or maximum, or both) for each specified alloying element, subject to the following restrictions for the heat analysis limits in mass percent:
(a) for wrought carbon steel products, the specified maximum limit is not to exceed: 0.10 for aluminum, 0.60 for silicon, and 0.050 for titanium;
(b) for carbon steel castings, the specified maximum limit is not to exceed: 0.10 for aluminum, 1.00 for silicon, and 0.050 for titanium.
(c) for **carbon steels** that are required to be rephosphorized, the specified minimum limit for phosphorus is not to be less than 0.040;
(d) for **carbon steels** that are required to be resulfurized, the specified minimum limit for sulfur is not to be less than 0.060;
(e) for **carbon steels** that are not required to be rephosphorized or resulfurized, the specified maximum limit is not to exceed: 0.60 for copper, 0.050 for phosphorus, and 0.060 for sulfur; and
(f) for **carbon steels** that are required to contain boron, copper, or lead, the specified minimum limit is not to exceed: 0.0005 for boron, 0.35 for copper, and 0.25 for lead.

cast analysis—Deprecated term. Use the preferred term **heat analysis**.

certificate of compliance, *n—in manufactured products*, a document that states that the product was manufactured, sampled, tested, and inspected in accordance with the requirements of the specification (including year of issue) and any other requirements specified in the purchase order or contract, and has been found to meet such requirements.

Discussion—A single document, containing test report information and certificate of compliance information, may be used.

[1] This terminology is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.92 on Terminology.

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[2] 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.

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

certifying organization, *n*—*in product specifications*, the entity responsible for the conformance and certification of the product to the specification requirements.

check analysis—Deprecated term. Use the preferred term **product analysis**.

coarse grain practice, *n*—a steelmaking practice for other than **stainless steel** that is intended to produce a **killed steel** in which aluminum, niobium (columbium), titanium, and vanadium are **residual elements**.

cold working, *n*—mechanical deformation of a metal at temperatures below its **recrystallization temperature**.

defect, *n*—an imperfection of sufficient magnitude to warrant rejection based on the specified requirements.

direct quenching, *n*—*in thermomechanical processing*, **quenching** immediately following the final hot deformation.

document, *n*—a written, printed, or electronic record that provides information, evidence, or official statements.

electronic data interchange, *n*—the computer to computer exchange of business information in a standardized format.

ellipsis, *n*—*in a tabular entry*, three periods (...) that indicate that there is no requirement.

ferroalloy, *n*—an alloy of iron and one or more other metals, for use as an addition to the molten metal during the manufacture of **steels**, nickel alloys, or cobalt alloys.

fine grain practice, *n*—a steelmaking practice for other than **stainless steel** that is intended to produce a **killed steel** that is capable of meeting the requirements specified for fine austenitic grain size.

DISCUSSION—It normally involves the addition of one or more austenitic grain refining elements in amounts that have been established by the steel producer as being sufficient. Austenitic grain refining elements include, but are not limited to, aluminum, niobium (columbium), titanium, and vanadium.

grain size, *n*—the dimensions of the grains or crystals in a polycrystalline metal, exclusive of twinned regions and subgrains when present.

DISCUSSION—**Grain size** is usually estimated or measured on the cross section of an aggregate of grains, and designated by an ASTM grain size number. (See Test Methods E 112.)

heat, *n*—a generic term denoting a specific **lot** of **steel**, based upon steelmaking and casting considerations.

DISCUSSION—Where it is necessary to be more definitive, the following more specific terms are used: **primary heat**, **multiple heat**, and **remelted heat**. In product specifications, the term **heat** generally is used, without qualification, to mean the **primary**, **multiple**, or **remelted heat**, whichever is applicable.

heat analysis, *n*—the chemical analysis determined by the steel producer as being representative of a specific **heat** of **steel**.

DISCUSSION—Where the analysis reported by the steel producer is not sufficiently complete for conformance with the heat analysis requirements of the applicable product specification to be fully assessed, the **manufacturer** may complete the assessment of conformance with such heat analysis requirements by using a product analysis for the **specified elements** that were not reported by the steel producer, provided that product analysis tolerances are not applied and the **heat analysis** is not altered.

heat number, *n*—the alpha, numeric, or alphanumeric designator used to identify a specific **heat** of **steel**.

high-strength low-alloy steel, *n*—a **steel**, other than a **carbon steel** or an **interstitial-free steel**, that conforms to a specification that requires the minimum content for each specified alloying element to be lower than the applicable limit in the definition for **alloy steel**, and the yield point or yield strength of the product to be at least 36 ksi or 250 MPa.

hot-cold working, *n*—the mechanical deformation of austenitic and precipitation hardening steels at a temperature just below the **recrystallization temperature** to increase the yield strength and hardness by plastic deformation or precipitation hardening effects induced by plastic deformation, or both.

hot working, *n*—mechanical deformation of a metal at temperatures above its **recrystallization temperature**.

imperfection, *n*—a material discontinuity or irregularity that is detectable by **inspection**.

inclusion shape control, *n*—the addition of elements during steel making in order to affect the inclusion morphology.

inspection, *n*—the process of measuring, examining, testing, gaging, or otherwise comparing the unit of product with the applicable requirements.

interstitial-free steel, *n*—a **steel** that has essentially all of its carbon and nitrogen chemically combined with stabilization elements rather than being present interstitially.

DISCUSSION—The heat analysis limits (minimum or maximum, or both) that are permitted to be prescribed in interstitial-free steel specifications are as given in the definition for **carbon steel**, except that the 0.050 % maximum limit for titanium does not apply.

killed steel, *n*—a **steel** deoxidized to such a level that essentially no reaction occurred between carbon and oxygen during solidification.

laser beam welding, *n*—a welding process that uses a laser beam as the heat source.

lot, *n*—a definite quantity of product manufactured under conditions that are considered uniform.

low-alloy steel, *n*—a **steel**, other than a **carbon steel** or an **interstitial-free steel**, that conforms to a specification that requires the minimum content for each specified alloying element to be lower than the applicable limit in the definition for **alloy steel**.

manufacturer, *n*—the organization responsible for the conversion of materials into products meeting the requirements of a product specification.

microalloyed steel, *n*—a **low-alloy steel** that conforms to a specification that requires the presence of one or more carbide-, nitride-, or carbonitride-forming elements, generally in individual concentrations less than 0.15 mass percent, to enhance strength.

DISCUSSION—The most common microalloying elements are niobium (columbium), titanium, and vanadium.

multiple heat, *n*—two or more molten **primary heats**, in whole or in part, combined in a common ladle or in a common non-oscillating mold.

Discussion—A **multiple heat** is identified by a single **heat number** representative of the **multiple heat**, or by the individual **heat numbers** of the **primary heats** contained in the **multiple heat**. The **heat analysis** of a **multiple heat** identified by a single **heat number** is the weighted average analysis of the individual **primary heats** contained in the **multiple heat**. Two or more molten **primary heats** sequentially strand cast (poured into an oscillating mold) constitute a series of individual **heats**, not a **multiple heat**.

nickel alloy, *n*—a material that conforms to a specification that requires by mass percent more nickel than any other element.

Discussion—In castings, the nickel content requirement is not normally stated in the specification and is not normally determined by chemical analysis, but is taken to be 100 % minus the sum of the mean values permitted by the specification for all other elements having a specified range or a specified maximum.

plate-as-rolled, *n*—the quantity of plate product rolled at one time, either from an individual slab or directly from an ingot.

Discussion—This term does not refer to the surface condition or the heat-treatment state of the material; a **plate-as-rolled** may be in the as-rolled condition, or may have received one or more surface treatments or **heat treatments**, or both.

primary heat, *n*—the product of a single cycle of a batch melting process.

Discussion—In the investment casting industry, the term *master heat* is used.

product analysis, *n*—a chemical analysis of a specimen taken from the semi-finished product or the finished product.

remelted heat, *n*—the product of the remelting of a **primary heat**, in whole or in part.

Discussion—In the investment casting industry, the term *sub-heat* is used.

residual element, *n*—*in* ***steel***, a specified or unspecified element, not intentionally added, originating in the raw materials, refractories, or surrounding atmospheres used in steel making.

rimmed steel, *n*—a **steel** that contained sufficient oxygen to generate carbon monoxide at the boundary between the solid metal and the remaining molten metal during solidification, resulting in an outer layer low in carbon.

semikilled steel, *n*—an incompletely deoxidized **steel** that contained sufficient oxygen to form enough entrapped carbon monoxide during solidification to offset solidification shrinkage.

specified element, *n*—*in* ***steel***, an element controlled to a specified minimum, maximum, or range, in accordance with the requirements of the applicable product specification.

stabilized stainless steel, *n*—a **stainless steel** that conforms to a specification that prescribes limits (minimum or range) for niobium (columbium), tantalum, titanium, or a combination thereof.

Discussion—Such limits are sometimes expressed as a function of the carbon and nitrogen contents. In an appropriately annealed condition, a **stabilized stainless steel** will resist sensitization to intergranular corrosion associated with the precipitation of chromium carbide at grain boundaries as a result of thermal exposure, such as **annealing, stress relieving**, welding, or high temperature service. Resistance to sensitization to intergranular corrosion is dependent upon the corrosivity of the environment. The condition of being stabilized with respect to sensitization is frequently demonstrated by passing one or more standard corrosion tests for sensitization.

stainless steel, *n*—a **steel** that conforms to a specification that requires, by mass percent, a minimum chromium content of 10.5 or more, and a maximum carbon content of less than 1.20.

steel, *n*—a material that conforms to a specification that requires, by mass percent, more iron than any other element and a maximum carbon content of generally less than 2.

Discussion—The iron content requirement is not normally stated in the specification and is not normally determined by chemical analysis, but is taken to be 100 % minus the sum of the mean values permitted by the specification for all other elements having a specified range or a specified maximum. For conformance purposes, this calculated value for iron is compared on an individual basis to the mean values permitted by the specification for each of the other elements having a specified range or a specified maximum. Some chromium-containing steels may contain more than 2 % carbon; however, 2 % carbon is generally considered to be the demarcation between **steel** and cast iron.

strain hardening, *n*—an increase in hardness and strength of a metal caused by plastic deformation at temperatures below its **recrystallization temperature**. (Syn. *work hardening*)

test record, *n*—a document or electronic record that contains the observations and derived data obtained by applying a given test method.

test report, *n*—a document that presents the applicable qualitative or quantitative results obtained by applying one or more given test methods.

Discussion—A single document, containing test report information and certificate of compliance information, may be used.

unspecified element, *n*—*in* ***steel***, an element not controlled to a specified minimum, maximum, or range, in accordance with the requirements of the applicable product specification.

3.2 *Definitions of Terms Relating to Heat Treatment of Steels:*

Ac_{cm}, Ac_1, Ac_3, Ac_4—See **transformation temperature**.

Ae_{cm}, Ae_1, Ae_3, Ae_4—See **transformation temperature**.

age hardening, *n*—hardening by **aging**, usually after rapid cooling or **cold working**.

aging, *n*—a change in the properties of certain **steels** that occurs at ambient or moderately elevated temperatures after hot working or a heat treatment (**quench aging, natural aging,** or **artificial aging**) or after a cold-working operation (**strain aging**).

Discussion—The change in properties is often, but not always, due to **precipitation hardening**, but never involves a change in the chemical composition of the **steel**.

annealing, *n*—a generic term covering any of several **heat treatments**.

DISCUSSION—This treatment is used for purposes such as reducing hardness, improving machinability, facilitating **cold working**, producing a desired microstructure, or obtaining desired mechanical, physical, or other properties. Where applicable, it is preferred that the following more specific terms be used: **box annealing, bright annealing, flame annealing, full annealing, graphitization annealing, intermediate annealing, isothermal annealing, process annealing, recrystallization annealing, spheroidizing**, and **subcritical annealing**. The term "**annealing**," without qualification, implies **full annealing**. Any process of **annealing** will usually reduce stresses; however, if the treatment is applied for the sole purpose of stress reduction, it should be designated **stress relieving**.

Ar_{cm}, Ar_1, Ar_3, Ar_4—See **transformation temperature**.

artificial aging, *n*—**aging** above room temperature.

austempering, *n*—**heat treatment** involving **quenching** a steel object from a temperature above the **transformation range** in a medium maintained at a temperature above the **martensite range** sufficiently fast to avoid the formation of high temperature transformation products, and then holding it at that temperature until transformation is complete.

austenitizing, *n*—forming austenite by heating a steel object above the **transformation range**.

baking, *n*—heating to a low temperature in order to remove gases.

batch furnace, *n*—a heating device within which steel objects are held stationary or oscillated during the thermal processing cycle.

blank carburizing, *n*—simulating the **carburizing** operation without introducing carbon.

DISCUSSION—This is usually accomplished by using an inert material in place of the carburizing agent, or by applying a suitable protective coating on the object being heat treated.

blank nitriding, *n*—simulating the nitriding operation without introducing nitrogen.

DISCUSSION—This is usually accomplished by using an inert material in place of the nitriding agent, or by applying a suitable protective coating on the object being heat treated.

bluing, *n*—subjecting the scale-free surface of a steel object to the action of air, steam, or other agents at a suitable temperature, thereby forming a thin blue film of oxide and improving the object's appearance and corrosion resistance.

DISCUSSION—This term is ordinarily applied to sheet, strip, or finished parts. It is used also to denote the heating of springs after fabrication in order to improve their properties.

box annealing, *n*—**annealing** in a sealed container under conditions that minimize oxidation.

DISCUSSION—The charge is usually heated slowly to a temperature below the **transformation range**, but sometimes above or within it, and is then cooled slowly.

bright annealing, *n*—**annealing** in a protective medium to prevent discoloration of the bright surface.

carbon potential, *n*—the carbon content at the surface of a specimen of pure iron in equilibrium with the carburizing medium considered, and under the conditions specified.

carbon restoration, *n*—replacing the carbon lost from the surface layer in previous processing by carburizing this layer to substantially the original carbon level.

carbonitriding, *n*—**case hardening** in which a suitable steel object is heated above Ac_1 in a gaseous atmosphere of such composition as to cause simultaneous absorption of carbon and nitrogen by the surface and, by diffusion, to create a concentration gradient.

carburizing, *n*—a process in which an austenitized steel object is brought into contact with a carbonaceous environment of sufficient carbon potential to cause absorption of carbon at the surface and, by diffusion, to create a concentration gradient.

case, *n—in case hardening*, the outer portion that has been made harder than the **core** as a result of altered composition or microstructure, or both, from treatments such as **carburizing, nitriding**, and **induction hardening**.

case hardening, *n*—a generic term covering any of several processes applicable to **steel** that change the chemical composition or microstructure, or both, of the surface layer.

DISCUSSION—The processes commonly used are: **carburizing** and **quench hardening**; **nitriding**; and **carbonitriding**. It is preferred that the applicable specific process name be used.

cementation, *n*—the introduction of one or more elements into the outer portion of a steel object by means of diffusion at high temperature.

cold treatment, *n*—exposing a steel object to temperatures below room temperature for the purpose of obtaining desired conditions or properties, such as dimensional or structural stability.

conditioning heat treatment, *n*—a preliminary **heat treatment** used to prepare a steel object for a desired reaction to a subsequent **heat treatment**.

continuous-conveyance furnace, *n*—a heating device through which steel objects are intentionally moved at a constant rate during the thermal processing cycle.

controlled cooling, *n*—cooling a steel object from an elevated temperature in a predetermined manner to avoid hardening, cracking, or internal damage, or to produce a desired microstructure or mechanical properties.

core, *n—in case hardening*, the interior portion of unaltered composition or microstructure, or both, of a case hardened steel object.

core, *n—in clad products*, the central portion of a multilayer composite metallic material.

critical cooling rate, *n*—the slowest rate of continuous cooling at which austenite can be cooled from above the **transformation range** to prevent its transformation above M_s.

cycle annealing, *n*—**annealing** employing a predetermined and closely controlled time-temperature cycle to produce specific properties or a specific microstructure.

decarburization, *n*—the loss of carbon from the surface of a steel object as a result of its being heated in a medium that reacts with the carbon.

differential heating, *n*—heating that intentionally produces a temperature gradient within a steel object such that, after cooling, a desired stress distribution or variation in properties is present within the object.

diffusion coating, *n*—any process whereby a base metal is either coated with another metal and heated to a sufficient temperature in a suitable environment, or exposed to a gaseous or liquid medium containing the other metal, thereby causing diffusion of the coating or other metal into the base metal, with a resultant change in the composition and properties of its surface.

direct quenching, *n—in thermochemical processing*, **quenching** immediately following the thermochemical treatment.

double aging, *n*—employment of two different aging treatments, in sequence, to control the type of precipitate formed from a supersaturated alloy matrix in order to obtain the desired properties.

DISCUSSION—the first aging treatment, sometimes referred to as intermediate or stabilizing, is usually carried out at a higher temperature than the second.

double tempering, *n*—a treatment in which a quench-hardened steel object is given two complete tempering cycles at substantially the same temperature for the purpose of ensuring completion of the tempering reaction and promoting stability of the resultant microstructure.

ferritizing anneal, *n*—a **heat treatment** that produces a predominantly ferritic matrix in a steel object.

flame annealing, *n*—**annealing** in which the heat is applied directly by a flame.

flame hardening, *n*—a process in which only the surface layer of a suitable steel object is heated by flame to above Ac_3 or Ac_{cm}, and then the object is **quenched**.

fog quenching, *n*—**quenching** in a mist.

full annealing, *n*—**annealing** a steel object by **austenitizing** it and then cooling it slowly through the **transformation range**.

DISCUSSION—The austenitizing temperature is usually above Ac_3 for hypoeutectoid steels and between Ac_1 and Ac_{cm} for hypereutectoid steels.

grain growth, *n*—an increase in the grain size of a steel object, usually as a result of exposure to elevated temperatures.

graphitization annealing, *n*—**annealing** a steel object in such a way that some or all of the carbon is precipitated as graphite.

hardenability, *n*—the property that determines the depth and distribution of hardness induced by **quenching** a steel object.

hardening, *n*—increasing the hardness by suitable treatment, usually involving heating and cooling.

DISCUSSION—Where applicable, it is preferred that the following more specific terms be used: **age hardening**, **case hardening**, **flame hardening**, **induction hardening**, **precipitation hardening**, and **quench hardening**.

heat treatment, *n*—heating and cooling a steel object in such a way as to obtain desired conditions or properties.

DISCUSSION—Heating for the sole purpose of hot working is excluded from the meaning of this definition.

homogeneous carburizing, *n*—a process that converts a low-carbon steel to one of substantially uniform and higher carbon content throughout the section, so that a specific response to **hardening** may be obtained.

homogenizing, *n*—holding a steel object at high temperature to eliminate or decrease chemical segregation by diffusion.

hot quenching, *n*—an imprecise term used to cover a variety of quenching procedures in which the quenching medium is maintained at a prescribed temperature above 160 °F or 70 °C.

induction hardening, *n—in surface hardening*, a process in which only the surface layer of a suitable steel object is heated by electrical induction to above Ac_3 or Ac_{cm}, and then the object is **quenched**.

induction hardening, *n—in through hardening*, a process in which a suitable steel object is heated by electrical induction to above Ac_3 or Ac_{cm} throughout its section, and then the object is **quenched**.

induction heating, *n*—heating by electrical induction.

intermediate annealing, *n*—**annealing** wrought steel objects at one or more stages during manufacture prior to final thermal treatment.

interrupted aging, *n*—**aging** at two or more temperatures, by steps, and cooling to room temperature after each step.

interrupted quenching, *n*—**quenching** in which the object being quenched is removed from the quenching medium while the object is at a temperature substantially higher than that of the quenching medium.

isothermal annealing, *n*—**austenitizing** a steel object and then cooling it to, and holding it at, a temperature at which austenite transforms to a ferrite-carbide aggregate.

isothermal transformation, *n*—a change in phase at any constant temperature.

M_f, M_s—See **transformation temperature**.

maraging, *n*—a precipitation hardening treatment applied to a special group of **alloy steels** to precipitate one or more intermetallic compounds in a matrix of essentially carbon-free martensite.

martempering, *n*—**quenching** an austenitized steel object in a medium at a temperature in the upper part of, or slightly above, the **martensite range**, holding it in the medium until its temperature is substantially uniform throughout, and then cooling it in air through the **martensite range**.

martensite range, *n*—the temperature interval between M_s and M_f.

natural aging, *n*—spontaneous aging of a super-saturated solid solution at room temperature.

nitriding, *n*—introducing nitrogen into a solid steel object by holding it at a suitable temperature in contact with a nitrogenous environment.

normalizing, *n*—heating a steel object to a suitable temperature above the **transformation range** and then cooling it in air to a temperature substantially below the **transformation range**.

overaging, *n*—**aging** under conditions of time and temperature greater than those required to obtain maximum change in a certain property, so that the property is altered away from the maximum.

overheating, *n*—heating a steel object to such a high temperature that excessive grain growth occurs.

DISCUSSION—Unlike burning, it may be possible to restore the original properties/microstructure by further heat treatment or mechanical working, or a combination thereof.

patenting, *n*—*in wire making,* heating a medium-carbon or high-carbon steel before wire drawing, or between drafts, to a temperature above the **transformation range**, and then cooling it in air, or a bath of molten lead or salt, to a temperature below Ae_1.

post-weld heat treatment, *n*—heating weldments immediately after welding, to provide **tempering**, **stress relieving**, or a controlled rate of cooling to prevent formation of a hard or brittle microstructure.

precipitation hardening, *n*—**hardening** caused by the precipitation of a constituent from a supersaturated solid solution.

precipitation heat treatment, *n*—**artificial aging** in which a constituent precipitates from a supersaturated solid solution.

preheating, *n*—*for tool steels,* heating to an intermediate temperature immediately before final **austenitizing**.

preheating, *n*—heating before welding, a mechanical treatment, or some further thermal treatment.

process annealing, *n*—*in the sheet and wire industries,* heating a steel object to a temperature close to, but below, Ac_1 and then cooling it, in order to soften it for further cold working.

progressive aging, *n*—**aging** by increasing the temperature in steps, or continuously, during the aging cycle.

quench aging, *n*—**aging** associated with **quenching** after **solution heat treatment**.

quench hardening, *n*—**hardening** a steel object by **austenitizing** it, and then cooling it rapidly enough that some or all of the austenite transforms to martensite.

DISCUSSION—The austenitizing temperature is usually above Ac_3 for hypoeutectoid steels and between Ac_1 and Ac_{cm} for hypereutectoid steels.

quenching, *n*—rapid cooling.

DISCUSSION—Where applicable, it is preferred that the following more specific terms be used: **fog quenching, hot quenching, interrupted quenching, selective quenching, spray quenching,** and **time quenching**.

recrystallization, *n*—the formation of a new grain structure through a nucleation and growth process.

DISCUSSION—This is commonly produced by subjecting a steel object, which may be strained, to suitable conditions of time and temperature.

recrystallization annealing, *n*—**annealing** a cold-worked steel object to produce a new grain structure without a change in phase.

recrystallization temperature, *n*—the approximate minimum temperature at which recrystallization of a cold-worked steel object occurs within a specified time.

secondary hardening, *n*—the hardening phenomenon that occurs during high-temperature **tempering** of certain **steels** containing one or more carbide-forming alloying elements.

selective heating, *n*—intentionally heating only certain portions of a steel object.

selective quenching, *n*—**quenching** only certain portions of a steel object.

semicontinuous-conveyance furnace, *n*—a heating device through which steel objects are intentionally moved in accordance with a predetermined start-stop-start pattern during the thermal processing cycle.

shell hardening, *n*—a surface hardening process in which a suitable steel object, when heated through and quench hardened, develops a martensitic layer or shell that closely follows the contour of the piece and surrounds a **core** of essentially pearlitic transformation product.

DISCUSSION—This result is accomplished by a proper balance between section size, **hardenability**, and severity of quench.

slack quenching, *n*—the incomplete **hardening** of a steel object due to **quenching** from the austenitizing temperature at a rate slower than the **critical cooling rate** for the particular steel composition, resulting in the formation of one or more transformation products in addition to martensite.

snap temper, *n*—a precautionary interim stress-relieving treatment applied to a high-hardenability steel immediately after **quenching** to prevent cracking because of delay in **tempering** it at the prescribed higher temperature.

soaking, *n*—prolonged holding at a selected temperature.

solution heat treatment, *n*—heating a steel object to a suitable temperature, holding it at that temperature long enough to cause one or more constituents to enter into solid solution, and then cooling it rapidly enough to hold such constituents in solution.

spheroidizing, *n*—heating and cooling a steel object to produce a spheroidal or globular form of carbide in its microstructure.

DISCUSSION—Spheroidizing methods commonly used are the following: (1) prolonged holding at a temperature just below Ae_1; (2) heating and cooling alternately between temperatures that are just above, and just below, Ae_1; (3) heating to a temperature above Ae_1 or Ae_3 and then cooling very slowly in the furnace or holding at a temperature just below Ae_1; (4) cooling, from the minimum temperature at which all carbide is dissolved, at a rate suitable to prevent the reformation of a carbide network, and then reheating in accordance with Method (1) or (2) above. (Applicable to hypereutectoid steels containing a carbide network.)

spray quenching, *n*—**quenching** in a spray of liquid.

stabilizing treatment, *n*—any treatment intended to stabilize the microstructure or dimensions of a steel object.

strain aging, *n*—**aging** induced by cold working.

stress relieving, *n*—heating a steel object to a suitable temperature, holding it long enough to reduce residual stresses, and then cooling it slowly enough to minimize the development of new residual stresses.

subcritical annealing, *n*—**annealing** at a temperature slightly below Ac_1.

surface hardening, *n*—a generic term covering any of several processes that, by **quench hardening** only, produce in a steel object a surface layer that is harder or more wear resistant than the **core**.

DISCUSSION—There is no significant alteration of the chemical composition of the surface layer. Where applicable, it is preferred that the following more specific terms be used: **induction hardening, flame hardening**, and **shell hardening**.

temper brittleness, *n*—brittleness that results when certain **steels** are held within, or are cooled slowly through, a certain range of temperature below the **transformation range**.

tempering, *n*—reheating a quench hardened or normalized steel object to a temperature below Ac_1, and then cooling it at any desired rate.

thermochemical treatment, *n*—a **heat treatment** carried out in a medium suitably chosen to produce a change in the chemical composition of the steel object by exchange with the medium.

time quenching, *n*—interrupted **quenching** in which the duration of holding in the quenching medium is controlled.

transformation ranges, *n*—those ranges of temperature within which austenite forms during heating and transforms during cooling.

DISCUSSION—The two ranges are distinct, sometimes overlapping but never coinciding. The limiting temperatures of the ranges are dependent upon the steel composition and the rate of change of temperature, particularly during cooling.

transformation temperature, *n*—the temperature at which a change in phase occurs, with the limiting temperatures of the **transformation ranges** designated using the following symbols:

Ac_{cm}—the temperature at which the solution of cementite in austenite is completed during heating.

Ac_1—the temperature at which austenite begins to form during heating.

Ac_3—the temperature at which transformation of ferrite to austenite is completed during heating.

Ac_4—the temperature at which austenite transforms to delta ferrite during heating.

Ae_1, Ae_3, Ae_{cm}, Ae_4—the temperatures of phase change at equilibrium.

Ar_{cm}—the temperature at which precipitation of cementite starts during cooling.

Ar_1—the temperature at which transformation of austenite to ferrite or to ferrite plus cementite is completed during cooling.

Ar_3—the temperature at which austenite begins to transform to ferrite during cooling.

Ar_4—the temperature at which delta ferrite transforms to austenite during cooling.

M_f—the temperature at which transformation of austenite to martensite is substantially completed during cooling.

M_s—the temperature at which transformation of austenite to martensite starts during cooling.

DISCUSSION—All of the above changes, except the formation of martensite, occur at lower temperatures during cooling than during heating, and are dependent upon the rate of change of temperature.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this terminology since the last issue, A 941 – 06, that may impact the use of this terminology. (Approved June 15, 2006)

(*1*) Added a definition for **nickel alloy** in 3.1.

Committee A01 has identified the location of selected changes to this terminology since the last issue, A 941 – 04a, that may impact the use of this terminology. (Approved March 15, 2006)

(*1*) Added a definition for **document** in 3.1.

Designation: A 928/A 928M – 05

Standard Specification for Ferritic/Austenitic (Duplex) Stainless Steel Pipe Electric Fusion Welded with Addition of Filler Metal[1]

This standard is issued under the fixed designation A 928/A 928M; 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 covers electric-fusion-welded steel pipe suitable for corrosive service.

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

1.2 This specification covers grades of ferritic/austenitic steel as indicated in Table 1. The selection of the proper alloy and requirements for heat treatment shall be at the discretion of the purchaser, dependent on the service conditions to be encountered.

1.3 Five classes of pipe are covered as follows:

1.3.1 *Class 1*—Pipe shall be double welded by processes using filler metal in all passes and shall be radiographed completely.

1.3.2 *Class 2*—Pipe shall be double welded by processes using filler metal in all passes. No radiograph is required.

1.3.3 *Class 3*—Pipe shall be single welded by processes using filler metal in all passes and shall be radiographed completely.

1.3.4 *Class 4*—Same as Class 3, except that the weld pass exposed to the inside pipe surface is permitted to be made without the addition of filler metal (see 6.2.2.1 and 6.2.2.2).

1.3.5 *Class 5*—Pipe shall be double welded by processes using filler metal in all passes and shall be spot radiographed.

1.4 Supplementary requirements covering provisions ranging from additional testing to formalized procedures for manufacturing practice are provided. Supplementary Requirements S1 through S4 are included as options to be specified in the purchase order when desired.

1.5 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 the specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 240/A 240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and General Applications

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

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

E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys

2.2 *ASME Boiler and Pressure Vessel Code:*[3]

Section III, Nuclear Vessels

Section VIII, Unfired Pressure Vessels

Section IX, Welding Qualifications

2.3 *AWS Specifications:*[4]

A 5.4 Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes

A 5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes

A 5.11 Nickel and Nickel-Alloy Covered Welding Electrodes

A 5.14 Nickel and Nickel-Alloy Bare Welding Rods and Electrodes

A 5.22 Flux Cored Corrosion-Resisting Chromium and Chromium-Nickel Steel Electrodes

A 5.30 Consumable Weld Inserts for Gas Tungsten Arc Welding

[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 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.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

[4] Available from The American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.

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

TABLE 1 Pipe and Filler Metal Specifications

UNS Designation	Grade[A]	ASTM Plate Specification No. and Grade	A 5.4		A 5.9		A 5.11		A 5.14		A 5.22		A 5.30	
			Class	UNS	Class	UNS	Class	UNS	Class	UNS	Class	UNS	Class	UNS
S31200	. . .	A 240 S31200	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
S31260	. . .	A 240 S31260	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
S31500	. . .	A 240 S31500	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
S31803	. . .	A 240 S31803	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
S32003	. . .	A 240 S32003	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
S32205	2205	A 240 S32205	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
S32304	2304	A 240 S32304	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
S32550	255	A 240 S32550	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
S32750	2507	A 240 S32750	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
S32900	329[B]	A 240 type 329	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
S32950	. . .	A 240 S32950	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
S32760	. . .	A 240 S32760	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
S32520	. . .	A 240 S32520	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

[A] Except as indicated, common name, not a trademark, widely used, not associated with any one producer.
[B] A grade designation originally assigned by the American Iron and Steel Institute (AISI).

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Specification A 999/A 999M and Terminology A 941 are applicable to this specification.

4. Ordering Information

4.1 It shall be the responsibility of the purchaser to specify all requirements that are necessary for product under this specification. Such requirements to be considered include, but are not limited to, the following:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (electric-fusion-welded pipe),

4.1.3 Grade (see Table 1),

4.1.4 Class (see 1.3),

4.1.5 Size (outside diameter and nominal wall thickness),

4.1.6 Length (specific or random),

4.1.7 End finish (section on ends of Specification A 999/A 999M),

4.1.8 Authorization for repair of plate defects by welding and subsequent heat treatment without prior approval, if such is intended (see 13.3),

4.1.9 Specification designation,

4.1.10 Special requirements,

4.1.11 Statement invoking requirements of 13.4, if such is intended,

4.1.12 Circumferential weld permissibility (see Section 17),

4.1.13 Supplementary Requirements (S1 through S4),

4.1.14 Applicable ASME Code, if known,

4.1.15 For ASME Code Section III applications, the service classification intended, and

4.1.16 Certification requirements (see section on certification of Specification A 999/A 999M).

5. General Requirements

5.1 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.

6. Materials and Manufacture

6.1 *Materials*—The steel plate material shall conform to the requirements of one of the grades of Specification A 240/A 240M, listed in Table 1.

6.2 *Welding*:

6.2.1 The joints shall be full penetration double-welded or single-welded butt joints using fusion welding processes as defined under 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 used (single or double) in making the weld. Where backing rings or strips are used, the ring or strip material shall be of the same P-Number (Table QW-422 of Section IX) as the plate being joined. Backing rings or strips shall be removed completely after welding, prior to any required radiography, and the exposed weld surface shall be examined visually for conformance to the requirements of 6.2.3. Welds made by procedures using backing strips or rings that remain in place are prohibited. Welding procedures and welding operators shall be qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

6.2.2 Except as provided in 6.2.2.1 and 6.2.2.2, welds shall be made in their entirety by processes involving the deposition of filler metal.

6.2.2.1 For Class 4 pipe using multiple passes, it is permitted to make the root-pass without the addition of filler metal.

6.2.2.2 For Class 4 pipe, it is permitted that the weld surface exposed inside the pipe be the result from a single pass made from the inside of the pipe without the addition of filler metal.

6.2.2.3 All single-welded pipe shall be radiographed completely.

6.2.3 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]. It is permitted to remove any weld reinforcement, at the option of the manufacturer or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be reasonably smooth and free of 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.

6.2.4 Weld defects shall be repaired by removal to sound metal and rewelding. Subsequent heat treatment and examination (that is, visual, radiographic, and dye penetrant) shall be as required on the original welds.

6.3 *Heat Treatment*:

6.3.1 Unless otherwise stated in the order, heat treatment shall be performed after welding and in accordance with the requirements of Table 2.

6.3.2 If the purchaser desires pipe without heat treatment subsequent to welding, the purchase order shall specify the following condition:

6.3.2.1 *No final heat treatment of pipe fabricated of plate that has been heat treated as required by Table 2 for the particular grade*. Each pipe supplied under this requirement shall be stenciled with the suffix "HT-O."

7. Chemical Composition

7.1 The chemical composition of the plate shall conform to the requirements of the applicable specification and grade listed in Table 1.

7.2 Unless otherwise specified in the purchase order, the chemical composition of the welding material shall conform to the requirements of the applicable AWS specification for the corresponding grade given in Table 1 or shall conform to the chemical composition specified for the plate, or shall, subject to purchaser approval, be a filler metal more highly alloyed than the base metal when needed for corrosion resistance or other properties. Use of a filler metal other than that listed in Table 1 or conforming to the chemical composition specified for the plate shall be reported and the filler metal identified on the certificate of tests. When nitrogen is a specified element for the ordered grade, the method of analysis shall be a matter of agreement between the purchaser and the manufacturer.

8. Heat Analysis

8.1 The chemical analysis of the steel shall be determined by the plate manufacturer and shall conform to the requirements for the particular grade as prescribed in Specification A 240/A 240M.

9. Product Analysis

9.1 At the request of the purchaser's inspector, an analysis of one length of flat-rolled stock from each heat, or from base metal and weld deposit from two pipes from each lot, shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel:

NPS Designator	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5, incl	200 or fraction thereof
6 and over	100 or fraction thereof

9.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Section 7, subject to the product analysis tolerances of Table 1 in Specification A 480/A 480M.

9.3 If the analysis of one of the tests specified in 8.1 or 9.1 does not conform to the requirements specified in Section 7, it is permitted to obtain an analysis of the base metal and weld deposit of each pipe from the same heat or lot, and all pipe conforming to the requirements shall be accepted.

10. Tensile Requirements

10.1 The plate used in making the pipe shall conform to the requirements as to tensile properties of the applicable specifications listed in Table 1. Tension tests made by the plate manufacturer shall qualify the plate material.

10.2 The transverse tension test taken across the welded joint specimen shall have a tensile strength not less than the specified minimum tensile strength of the plate.

11. Permissible Variations of Dimensions for Thin-Wall Pipe

11.1 For thin-wall pipe, defined as pipe having a wall thickness of 3 % or less of the specified outside diameter, the diameter tolerance, as listed in Specification A 999/A 999M, shall apply only to the mean of the extreme (maximum and minimum) outside diameter readings in any one cross section.

11.2 For thin-wall pipe, the difference in extreme outside readings (called the ovality) in any one section shall not exceed twice the permissible variations in outside diameter for the specified diameter as listed in Specification A 999/A 999M.

12. Transverse Guided-Bend Weld Tests

12.1 Two bend test specimens shall be taken transversely from the pipe. Except as provided in 12.2, one shall be subject to a face guided-bend test and the second to a root guided-bend test. One specimen shall be bent with the inside surface of the pipe against the plunger, and the other with the outside surface against the plunger.

TABLE 2 Heat Treatment

UNS Designation	Grade[A]	Temperature, °F [°C]	Quench
S31200	. . .	1920–2010 [1050–1100]	rapid cooling in water
S31260	. . .	1870–2010 [1020–1100]	rapid cooling in water
S31500	. . .	1800–1900 [980–1040]	rapid cooling in air or water
S31803	. . .	1870–2010 [1020–1100]	rapid cooling in air or water
S32003	. . .	1850–2010 [1010–1100]	rapid cooling in air or water
S32205	2205	1870–2010 [1020–1100]	rapid cooling in air or water
S32304	2304	1700–1920 [925–1050]	rapid cooling in air or water
S32550	255	1900 [1040], min	rapid cooling in air or water
S32750	2507	1880–2060 [1025–1125]	rapid cooling in air or water
S32900	329[B]	1700–1750 [925–955]	rapid cooling in air or water
S32950	. . .	1820–1880 [990–1025]	rapid cooling in air or water
S32760	. . .	2010–2085 [1100–1140]	rapid cooling in air or water
S32520	. . .	1975–2050 [1080–1120]	rapid cooling in air or water

[A] Except as indicated, common name, not a trademark, widely used, not associated with any one producer.
[B] A grade designation originally assigned by the American Iron and Steel Institute (AISI).

12.2 For specified wall thicknesses over ⅜ in. [9.5 mm] but less than ¾ in. [19 mm], side-bend tests may be made instead of the face and root-bend tests. For specified wall thicknesses ¾ in. [19 mm] and over, both specimens shall be subjected to the side-bend tests. Side-bend specimens shall be bent so that one of the side surfaces becomes the convex surface of the bend specimen.

12.3 The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. [3 mm] in any direction are present in the weld metal or between the weld and the pipe metal after bending. Cracks that originate along edges of the specimen during testing, and that are less than ¼ in. [6.5 mm] measured in any direction, shall not be considered.

13. Workmanship, Finish, and Appearance

13.1 The finished pipe shall have a workmanlike finish.

13.2 *Repair of Plate Defects by Machining or Grinding*—Pipe showing slivers may be machined or ground inside or outside to a depth that shall ensure the removal of all included scale and slivers, providing the wall thickness is not reduced below the specified minimum wall thickness. Machining or grinding shall follow inspection of the pipe as rolled, and it shall be followed by supplementary visual inspection.

13.3 *Repair of Plate Defects by Welding*— Defects that violate minimum wall thickness may be repaired by welding, but only with the approval of the purchaser. Areas shall be prepared suitably for welding with tightly closed defects removed by grinding. Open, clean defects, such as pits or impressions, may require no preparation. All welders, welding operators, and weld procedures shall be qualified to the ASME Boiler and Pressure Vessel Code, Section IX. Unless the purchaser specifies otherwise, pipe required to be heat treated under the provisions of 6.3 shall be heat treated or reheat treated following repair welding. Repaired lengths, where repair depth is greater than ¼ of the thickness, shall be pressure tested or repressure tested after repair and heat treatment (if any). Repair welds shall also be examined by suitable nondestructive examination techniques, including any techniques required specifically of the primary weld.

13.4 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser is permitted to require in the purchase order that a passivating treatment be applied.

14. Test Specimens and Methods of Testing

14.1 Transverse tension and bend test specimens shall be taken from the end of the finished pipe; the transverse tension and bend test specimens shall be flattened cold before final machining to size.

14.2 As an alternative to the requirements of 14.1, the manufacturer is permitted to take the test specimens from a test plate of the same material as the pipe, which is attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

14.3 Tension test specimens shall be made in accordance with Section IX, Part 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.

14.3.1 Reduced-section specimens conforming to the requirements given in QW-462.1(b) are permitted to be used for tension tests on all thicknesses of pipe having outside diameters greater than 3 in. [76 mm].

14.3.2 Turned specimens conforming to the requirements of QW-462.1(d) are permitted to be used for tension tests.

14.3.2.1 If turned specimens are used as given in 14.3.2.2 and 14.4, one complete set shall be made for each required tension test.

14.3.2.2 For thicknesses over 1¼ in. [32 mm], multiple specimens shall be cut through the full thickness of the weld with their centers parallel to the material surface and not over 1 in. [25 mm] apart. The centers of the specimens adjacent to material surfaces shall not exceed ⅝ in. [16 mm] from the surface.

14.4 The test specimens shall not be cut from the pipe or test plate until after final heat treatment.

15. Mechanical Tests Required

15.1 *Transverse Tension Test*—One test shall be made to represent each lot (see Note 2) of finished pipe.

NOTE 2—The term lot is defined in 9.1.

15.2 *Transverse Guided-Bend Test*—One test (two specimens) shall be made to represent each lot (see Note 2) of finished pipe.

15.3 *Nondestructive Test*—Each length of pipe shall be subjected to a hydrostatic test as defined in 15.3.1 or, with the approval of the purchaser, each length of pipe having a wall thickness up through 0.165 in. (4.2 mm) shall be subjected to a nondestructive electric test as defined in 15.3.2.

15.3.1 *Hydrostatic Test*—Each length of pipe shall be subjected to a hydrostatic test in accordance with Specification A 999/A 999M, unless specifically exempted under the provision of 15.3.1.1. Pressure shall be held for a sufficient time to permit the inspector to examine the entire length of the welded seam.

15.3.1.1 With the agreement of the manufacturer, the purchaser is permitted to complete the hydrostatic test requirement with the system pressure test, which may be lower or higher than the specification test pressure, but in no case shall the test pressure be lower than the system design pressure. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory marking the letters NH.

15.3.2 *Nondestructive Electric Test*—Each length of pipe shall be subjected to a nondestructive electric test in accordance with Practice E 426.

15.3.2.1 For pipe up through NPS 4, the eddy-current test shall be applied to the total pipe area. For pipe larger than NPS 4, the eddy-current test is permitted, at the option of the producer, to be applied to the weld area only rather than the total pipe area.

16. Radiographic Examination

16.1 For Classes 1, 3, and 4 pipe, all welded joints shall be examined completely by radiography.

16.2 For Class 5 pipe, the welded joints shall be spot radiographed to the extent of not less than 12 in. [300 mm] of radiograph per 50 ft [15 m] of weld.

16.3 For Classes 1, 3, and 4 pipe, radiographic examination shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, latest edition, Paragraph UW-51.

16.4 For Class 5 pipe, radiographic examination shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest edition, Paragraph UW-52.

16.5 Radiographic examination is permitted to be performed prior to heat treatment.

17. Lengths

17.1 Circumferentially welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

18. Product Marking

18.1 In addition to the marking prescribed in Specification A 999/A 999M, the markings of each length of pipe shall include the plate material designations as shown in Table 1, the marking requirements of 6.3 and 15.3, and Class 1, 2, 3, or 4, as appropriate (see 1.3).

19. Keywords

19.1 arc welded steel pipe; corrosive service; duplex (austenitic-ferritic) stainless steel; fusion welded steel pipe; steel pipe; welded steel pipe

SUPPLEMENTARY REQUIREMENTS

FOR PIPE REQUIRING SPECIAL CONSIDERATION

One or more of the following supplementary requirements shall apply when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and the manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical requirements shall be rejected.

S2. Tension and Bend Tests

S2.1 Tension tests (see Section 10) and bend tests (see Section 12) shall be made on specimens to represent each length of pipe. Failure of any test specimen to meet the requirements shall be cause for the rejection of the pipe length represented.

S3. Penetration Oil and Powder Examination

S3.1 All welded joints shall be subjected to examination by a penetrant oil and powder method. The details of the method and the disposition of flaws detected shall be a matter for agreement between the purchaser and the manufacturer.

S4. Ferrite Control in Weld Deposits

S4.1 The ferrite content of the deposited weld metal in any length of pipe may be determined. The procedural details pertaining to this subject (that is, welding, plate and weld deposit chemistry, testing equipment and method, number and location of test sites, and ferrite control limits) shall be a matter for agreement between the purchaser and the manufacturer.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 928/A 928M - 04, that may impact the use of this specification. (Approved September 1, 2005)

(*1*) Added S32003 to Table 1 and Table 2.

Designation: A 908 – 03

Standard Specification for Stainless Steel Needle Tubing[1]

This standard is issued under the fixed designation A 908; 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*

1.1 This specification covers austenitic, stainless steel, needle tubing in hard-drawn tempers for industrial applications.

1.2 In general, needle tubing describes small-diameter tubing with outside diameters (ODs) in the range of 0.008 to 0.203 in. (0.2 to 5.2 mm) with nominal wall thicknesses in the range of 0.002 to 0.015 in. (0.05 to 0.4 mm). Needle tubing gages are normally 6 through 33.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes[2]

3. Ordering Information

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

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

3.1.2 Gage or size (outside diameter and minimum wall thickness),

3.1.3 Length (specific or random), and

3.1.4 Test report required (see the section on certification in Specification A 1016/A 1016M).

4. Process

4.1 An electric furnace or other similar primary melting process with or without degassing or refining may be used.

TABLE 1 Chemical Requirements

Carbon	0.08 max
Manganese	2.00 max
Phosphorous	0.040 max
Sulfur	0.030 max
Silicon	0.75 max
Chromium	18.0–20.0
Nickel	8.0–11.0

5. General Requirements

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

TABLE 2 Tensile Requirements

Tensile strength, ksi (MPa)	150–200 (1030–1370)

6. Manufacture

6.1 Needle tubing shall be made by the seamless or welded and drawn process and shall be furnished in the hard-drawn temper condition.

7. Heat Treatment

7.1 Unless otherwise specified by the purchaser, no heat treatment is required.

8. Chemical Composition

8.1 Stainless steel, Type 304, UNS S30400, in accordance with Table 1 shall be used.

8.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the manufacturer from samples made during the pour. The chemical composition thus determined shall meet the requirements of Table 1.

8.3 *Product Analysis*—An analysis may be made by the purchaser from finished tubing. The chemical composition thus determined shall meet the requirements of Table 1.

[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.

Current edition approved April 10, 2003. Published May 2003. Originally approved in 1991. Last previous edition approved in 1998 as A 908-91 (1998).

[2] *Annual Book of ASTM Standards*, Vol 01.01.

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

9. Mechanical Properties

9.1 *Tensile Requirements*—The tubing shall meet the tensile properties specified in Table 2. Yield strength, elongation, and hardness tests are not required for needle tubing.

9.2 *Number of Tests*—Two tension tests for each 5000 ft of product per heat shall be performed.

10. Dimensions

10.1 *Sizes and Tolerances*—Needle tubing sizes and dimensions shall be in accordance with Table 3.

11. Keywords

11.1 needle tubing; stainless steel

TABLE 3 Sizes and Tolerances

Gage No.	OD, in.	OD Tolerance, in. (±)	Nominal Wall, in.	Wall Tolerance, in. (±)
6	0.203	0.001	0.015	0.001
7	0.180	0.001	0.015	0.001
8	0.165	0.001	0.015	0.001
9	0.148	0.001	0.015	0.001
10	0.134	0.001	0.014	0.001
11	0.120	0.001	0.013	0.001
12	0.109	0.001	0.012	0.001
13	0.095	0.001	0.012	0.001
14	0.083	0.001	0.010	0.001
15	0.072	0.0005	0.009	0.0005
16	0.065	0.0005	0.009	0.0005
17	0.059	0.0005	0.009	0.0005
18	0.050	0.0005	0.0085	0.0005
19	0.0425	0.0005	0.00775	0.0005
20	0.0355	+0.0005/−0.000	0.00625	+0.000/−0.0005
21	0.032	+0.0005/−0.000	0.00625	+0.000/−0.0005
22	0.028	+0.0005/−0.000	0.00625	+0.000/−0.0005
23	0.025	+0.0005/−0.000	0.00625	+0.000/−0.0005
24	0.022	+0.0005/−0.000	0.00525	+0.000/−0.0005
25	0.020	+0.0005/−0.000	0.00525	+0.000/−0.0005
26	0.018	+0.0005/−0.000	0.00425	+0.000/−0.0005
27	0.016	+0.0005/−0.000	0.00425	+0.000/−0.0005
28	0.014	+0.0005/−0.000	0.0035	0.00025
29	0.013	+0.0005/−0.000	0.003	0.00025
30	0.012	+0.0005/−0.000	0.003	0.00025
31	0.010	+0.0005/−0.000	0.0025	0.00025
32	0.009	+0.0005/−0.000	0.0025	0.00025
33	0.008	+0.0005/−0.000	0.002	0.00025

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last edition (A 908-91 (1998)) that may impact the use of this standard (approved April 2003).

(1) Replaced Specification A 450/A 450M with Specification A 1016/A 1016M.

Designation: A 872/A 872M – 07a

Standard Specification for Centrifugally Cast Ferritic/Austenitic Stainless Steel Pipe for Corrosive Environments[1]

This standard is issued under the fixed designation A 872/A 872M; 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 covers centrifugally cast ferritic/austenitic steel pipe intended for general corrosive service. These steels are susceptible to embrittlement if used for prolonged periods at elevated temperatures.

1.2 Optional supplementary requirements are provided when additional testing may be required.

1.3 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of each other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use

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

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 94 Guide for Radiographic Examination

E 165 Test Method for Liquid Penetrant Examination

E 186 Reference Radiographs for Heavy-Walled (2 to 4½-in. [51 to 114-mm]) Steel Castings

E 280 Reference Radiographs for Heavy-Walled (4½ to 12-in. [114 to 305-mm]) Steel Castings

E 340 Test Method for Macroetching Metals and Alloys

E 446 Reference Radiographs for Steel Castings Up to 2 in. [51 mm] in Thickness

2.2 *ASME Boiler and Pressure Vessel Code:*

Section IX Welding Qualifications[3]

2.3 *ASTM Adjuncts:*

Adjunct E 186 Reference Radiographs—Transparencies in Ringbinders, 3 Volumes[4]

Adjunct E 280 Reference Radiographs—Transparencies in Ringbinders, 2 Volumes[5]

Adjunct E 446 Reference Radiographs—Transparencies in Ringbinders, 3 Volumes[6]

3. Ordering Information

3.1 Orders for material to this specification shall 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 (centrifugally cast ferritic/austenitic steel pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (outside or inside diameter and minimum wall thickness in inches [millimetres]),

3.1.5 Length (specific or random, Specification A 999/A 999M),

3.1.6 End finish of Specification A 999/A 999M,

3.1.7 Optional Requirements (S1 through S6),

3.1.8 Test report required (Section 12), and

3.1.9 Special requirements or additions to the 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 A01.18 on Castings.

Current edition approved March 1, 2007. Published April 2007. Originally approved in 1977. Last previous edition approved in 2007 as A 872/A 872M – 07.

[2] 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.

[3] Available from American Society of Mechanical Engineers (ASME International), Three Park Ave., New York, NY 10016-5990.

[4] Available from ASTM International Headquarters. Request RRE018601 for Vol I, RRE018602 for Vol II, and RRE018603 for Vol III.

[5] Available from ASTM International Headquarters. Request for RRE028001 Vol I and RRE028002 for Vol II.

[6] Available from ASTM International Headquarters. Request for RRE044601 Vol I, RRE044602 for Vol II, and RRE044603 for Vol III.

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

TABLE 1 Chemical Requirements

Element	Grade		
	UNS J93183	UNS J93550	UNS J94300 CD4MCuMN
C	0.030 max	0.030 max	0.04
Mn	2.0 max	2.0 max	0.50–1.50
P	0.040 max	0.040 max	0.04
S	0.030 max	0.030 max	0.04
Si	2.0 max	2.0 max	1.10 max
Ni	4.00–6.00	5.00–8.00	4.5–6.0
Cr	20.0–23.0	23.0–26.0	24.5–26.5
Mo	2.00–4.00	2.00–4.00	2.5–4.0
N	0.08–0.25	0.08–0.25	0.18–0.26
Cu	1.00 max	1.00 max	1.3–3.0
Co	0.50–1.50	0.50–1.50	...

4. General Requirements

4.1 Material furnished under 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 *Manufacture*:

5.1.1 The pipe shall be made by the centrifugal casting process.

5.1.2 All pipes shall be furnished in the heat-treated condition as shown in Table 2.

5.1.3 *Machining*—The pipe shall be machined on the inner surface and may be supplied either machined or unmachined in the outer surface. All machining shall be to a roughness value agreed upon between the manufacturer and purchaser.

6. Chemical Composition

6.1 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of elements specified in Table 1. The analysis shall be made on a test sample taken preferably during the pouring of the heat. The chemical composition thus determined shall conform to the requirements specified in Table 1.

6.2 *Product Analysis*—A product analysis may be made by the purchaser. The sample for analysis shall be selected so as to be thoroughly representative of the pipe being analyzed. The chemical composition thus determined shall conform to the requirements specified in Table 1.

6.3 To determine conformance with the chemical analysis requirements, an observed value or calculated value shall be rounded in accordance with Practice E 29 to the nearest unit in the last right-hand place of values listed in Table 1.

7. Tensile Requirements

7.1 *Testing*—Steel used for the castings shall conform to the tensile and hardness requirements specified in Table 3.

7.2 *Test Specimens*:

7.2.1 Test bars shall be taken from heat-treated castings.

7.2.2 Tension test specimens shall be machined to the form and dimensions shown in Figs. 5 or 6 of Test Methods and Definitions A 370.

7.3 *Number of Tests*:

7.3.1 One tension test shall be made from each heat.

7.3.2 If a specimen is machined improperly or flaws are revealed by machining or during testing, the specimen may be discarded and another substituted from the same heat.

7.4 *Retests*—If the results of the mechanical test for any heat do not conform to the requirements specified, the casting may be reheat treated and retested, but this may not be solution treated more than twice.

8. Quality

8.1 The surface of the casting shall be examined visually and shall be free of cracks and hot tears. Other surface defects shall be judged in accordance with visual acceptance criteria that may be specified in the order.

9. Rework and Retreatment

9.1 Defects as defined in Section 9 shall be removed and their removal verified by visual inspection of the resultant cavities. Defects that are located by inspection using Supplementary Requirement S4, S5, or S6 shall be removed or reduced to an acceptable size.

9.2 If removal of the defect does not infringe upon the minimum wall thickness, the depression shall be blended uniformly into the surrounding surface.

TABLE 2 Heat Treatment Requirements

Grade	Condition	
	Temperature, °F [°C]	Quenching
UNS J93183	1920–2100 [1050–1150]	Water quench or rapid cooling by other means
UNS J93550	1920–2100 [1050–1150]	Water quench or rapid cooling by other means
UNS J94300 CD4MCuMN	1900 minimum	Water quench or rapid cooling by other means

TABLE 3 Tensile and Hardness Requirements

Requirement	Grade		
	UNS J93183	UNS J93550	UNS J94300 CD4MCuMN
Tensile strength, min, ksi [MPa]	90 [620]	90 [620]	110 [760]
Yield strength, min, ksi [MPa]	65 [450]	65 [450]	70 [480]
Elongation in 2 in. or 50 mm, min, %	25	20	20
Hardness, max:			
Brinell	290	297	...
Rockwell C	30.5	31.5	...

9.3 If the cavity resulting from defect removal infringes upon the minimum wall thickness, weld repair is permitted subject to the purchaser's approval. The composition of the weld rod used shall be suitable for the composition of the metal being welded.

9.3.1 Practice A 488/A 488M or ASME Boiler and Pressure Vessel Code, Section IX shall be used as a guide for welder and procedure qualification and shall be by agreement between the purchaser and the manufacturer. All repair welds shall be inspected to the same quality standard used to inspect the casting.

10. Permissible Variations in Dimensions

10.1 *Thickness*—The wall thickness shall not vary over that specified by more than ⅛ in. [3 mm]. There shall be no variation under the specified wall thickness.

11. Rejection

11.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the pipe may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

12. Certification

12.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured sampled, tested, and inspected in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

13. Product Marking

13.1 Each length of pipe shall be legibly marked with the manufacturer's name or brand, the specification number, and the grade. In addition, heat numbers or special numbers that are traceable to heat numbers, shall be marked on each length of pipe.

14. Keywords

14.1 casting; centrifugal casting; corrosive service; ferritic/austenitic stainless steel; pipe

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon between the manufacturer and the purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Additional Tension Tests

S1.1 Additional tension tests shall be made at a temperature to be specified by the customer, and the properties to be met are a matter of agreement between purchaser and manufacturer.

S2. Flattening Test

S2.1 The flattening test shall be made on specimens from one or both ends of each length of pipe. If the specimen from any end of any length fails to conform to the requirements of Specification A 999/A 999M, that length shall be rejected.

S3. Etching Test

S3.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E of Test Method E 340. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material, free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of required tests per pipe shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S4. Radiographic Examination

S4.1 The castings shall be examined for internal defects by means of X rays or gamma rays. The inspection procedure shall be in accordance with Guide E 94 and the types and degrees of discontinuities considered shall be judged by Reference Radiographs E 186, E 280, or E 446. The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser.

S5. Liquid Penetrant Examination

S5.1 The castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The method of performing the liquid penetrant test shall be in accordance with Test Method E 165. The areas to be inspected, the methods, and types of liquid penetrants to be used, the developing procedure, and the basis for acceptance shall be as specified on the inquiry or contract or both, or as agreed upon between the manufacturer and the purchaser.

S6. Hydrostatic Test

S6.1 Each length of pipe shall be hydrostatically tested in accordance with Specification A 999/A 999M. Test pressure may be mutually agreed upon between the manufacturer and the purchaser.

S6.2 It is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work has been performed on the casting. In such cases, the foundry is responsible for the satisfactory performance of the casting when it is so tested.

S7. Charpy Impact Test

S7.1 The Charpy Impact Test shall be carried out in accordance with the requirements of Specification A 781/A 781M. The properties shall meet the requirements specified in Table S7.1.

TABLE S7.1 Impact Requirements

Grade	UNS J93183	UNS J93550	UNS J94300 CD4MCuMN
Energy value, ft.lbf [J] min for single specimen	...	...	35 [48]
Testing Temperature °F [°C]	...	...	0 [-18]

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 872/A 872M – 07, that may impact the use of this specification. (Approved March 1, 2007)

(*1*) Added requirements for Grade J93550 in Table 2.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 872/A 872M – 05, that may impact the use of this specification. (Approved February 1, 2007)

(*1*) Added UNS number to CD4MCuMN in Tables 1-3.

(*2*) Added new Table S7.1.

Designation: A 865/A 865M – 06

Standard Specification for Threaded Couplings, Steel, Black or Zinc-Coated (Galvanized) Welded or Seamless, for Use in Steel Pipe Joints[1]

This standard is issued under the fixed designation A 865/A 865M; 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 covers black or galvanized welded or seamless threaded steel couplings for use with steel pipe in NPS ⅛ to NPS 20 [DN 6 to DN 500] inclusive (Note 1). Couplings ordered under this specification are intended for the uses outlined in the pipe specifications referencing this specification.

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

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. 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.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment

B 6 Specification for Zinc

E 376 Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Examination Methods

2.2 *ANSI Standard:*

B 1.20.1 Pipe Threads[3]

2.3 *API Standards:*

5B Specification for Threading, Gaging, and Thread Inspection of Casing, Tubing, and Line Pipe Threads[4]

5L Specification for Line Pipe[4]

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 Specification number,

3.1.2 Quantity (pieces),

3.1.3 Name of material (steel pipe-couplings),

3.1.4 Method of manufacture (welded or seamless),

3.1.5 Finish (black or Type I or Type II) galvanized (see 8.1),

3.1.6 Size (NPS designator [DN]),

3.1.7 Standard or extra-strong classification,

3.1.8 Taper tapped-couplings for NPS 2 [DN 50] and smaller, either recessed or non-recessed, if desired, and

3.1.9 Certification (see 11.3), if required.

4. Process

4.1 The steel for both welded and seamless couplings shall be made by one or more of the following processes: open-hearth, electric-furnace, or basic-oxygen.

4.2 Welded couplings NPS 3 ½ [DN 90] and under may be butt-welded, unless otherwise specified. Welded couplings over NPS 3 ½ [DN 90] shall be electric-welded.

5. Chemical Composition

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

6. Dimensions

6.1 Coupling dimensions are listed in Tables 2-4 and Figs. 1-3.

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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 A01.09 on Carbon Steel Tubular Products.

Current edition approved July 1, 2006. Published August 2006. Originally approved in 1986. Last previous edition approved in 2003 as A 865-03.

[2] 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.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[4] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005.

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

TABLE 1 Chemical Requirements

	Composition, max %	
	Phosphorus	Sulfur
All processes	0.14	0.35

7. Permissible Variations in Dimensions

7.1 *Diameter*—For couplings NPS 1 ½ [DN 40] and under, the outside diameter at any point shall not vary more than 1⁄64 in. [0.4 mm] over nor more than 1⁄32 in. [0.8 mm] under the standard specified. For couplings NPS 2 [DN 50] and over, the outside diameter shall not vary more than ±1 % from the standard specified.

7.2 *Threads*—The variation of the threads shall not exceed ±1 ½ turns for straight tapped and ±1 turn for taper tapped from nominal as determined using gages and the gaging practices in ANSI B 1.20.1.

8. Galvanized Couplings

8.1 Galvanized couplings may be coated with zinc by either the hot-dipped (Type 1) or by the electrogalvanizing process. (Type II) as specified by the purchaser. The zinc used for the coating shall be any grade of zinc conforming to Specification B 6.

8.2 Hot-dipped galvanized couplings are coated prior to threading.

8.2.1 The minimum weight of the zinc coating on the outside surface of the hot-dipped galvanized couplings shall be equivalent to 1.6 oz/ft^2 [490 g/m^2].

8.2.2 The weight of the zinc coating on the outside surface shall be determined by the use of a magnetic thickness gage, using the procedure in Practice E 376 or using another method that is mutually agreed upon between the purchaser and the manufacturer.

8.3 Electrogalvanized couplings are coated either before or after threading.

8.3.1 The weight of the zinc coating on the outside surface of the electrogalvanized couplings shall be equivalent to 0.18 oz/ft^2 [55 g/m^2] (see also 8.2.2)

8.4 *Sampling*—Samples of couplings sufficient to determine their conformance with the requirements of this specification, shall be taken at random for each lot of couplings of the same size.

9. Threading

9.1 The coupling threads shall be in accordance with ANSI B 1.20.1. The couplings shall be applied handling tight, unless power tight is specified on the order. Taper-tapped couplings shall be furnished on all weights of pipe NPS 2 ½ [DN 65] and larger. For sizes NPS 2 [DN 50] and smaller, it is regular practice to furnish straight-tapped couplings for standard weight pipe and taper-tapped couplings for extra-strong and double-extra-strong pipe. Taper-tapped couplings may be specified for pipe sizes NPS 2 [DN 50] and under. Taper-tapped couplings furnished for standard-weight pipe may be nonrecessed (see Table 3) or recessed (see Table 4). Couplings furnished for extra-strong and double-extra strong pipe are recessed. Recessed couplings (Table 4) conform to API Specification 5L.

10. Finish

10.1 The finished couplings shall be free of defects.

10.2 The zinc coating on galvanized couplings shall be free of voids or excessive roughness.

11. Inspection and Certification

11.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

11.2 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified herein. Except as specified in the contract order, the producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

11.3 The manufacturer or supplier shall upon request, furnish to the purchaser a certificate of inspection stating that the material has been sampled, tested, and inspected in accordance with this specification, and has been found to meet the requirements.

12. Rejection

12.1 Each coupling received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based upon the inspection, the coupling may be rejected and the manufacturer shall be notified. Disposition of rejected couplings shall be the matter of agreement between the manufacturer and the purchaser.

13. Product Marking and Packing

13.1 Each coupling shall be marked with the trademark of the manufacturer by metal stamp or paint.

13.2 The cartons in which the couplings are packed shall bear the manufacturer's name or trademark, the NPS [DN] designator, the finish (black or galvanized), and the number of pieces.

13.3 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with Practice A 700.

13.4 *Bar Coding*—In addition to the requirements in 13.1, 13.2, and 13.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

14. Keywords

14.1 black steel pipe; seamless steel pipe; steel pipe; welded steel pipe; zinc coated steel pipe

TABLE 2 Coupling Thread Dimension—Straight-Tapped (NPSC) for Standard Weight Pipe

NPS Designator	DN Designator	Threads/in.	Outside diameter, in. [mm] *W*	Coupling min length, in. [mm] N_L	Pitch diameter, in. [mm]	
					min	max
⅛	6	27	0.563 [14.3]	¾ [19]	0.370 [9.4]	0.377 [9.6]
¼	8	18	0.719 [18.3]	1⅛ [29]	0.486 [12.3]	0.497 [12.6]
⅜	10	18	0.875 [22.2]	1⅛ [29]	0.622 [15.8]	0.632 [16.1]
½	15	14	1.063 [27.0]	1½ [38]	0.772 [19.6]	0.785 [19.9]
¾	20	14	1.313 [33.4]	1 9/16 [40]	0.982 [24.9]	0.996 [25.3]
1	25	11½	1.576 [40.0]	1 15/16 [49]	1.231 [31.3]	1.247 [31.7]
1¼	32	11½	1.900 [48.3]	2 [50]	1.575 [40.0]	1.592 [40.4]
1½	40	11½	2.200 [55.9]	2 [50]	1.814 [46.1]	1.831 [46.5]
2	50	11½	2.750 [69.8]	2 1/16 [52]	2.288 [58.1]	2.304 [58.5]
		Outside diameter tolerances:	For NPS 1 ½ [DN 40] and under		+0.015 in. [0.4 mm] −0.031 in. [0.8 mm]	
			For NPS 2 [DN 50] and over		±1 %	

TABLE 3 Coupling Thread Dimensions—Taper-Tapped (NPT) Non-Recessed for Standard-Weight Pipe

NPS Designator	DN Designator	Threads/in.	Outside diameter, in. [mm] *W*	Coupling min length, in. [mm] N_L	Pitch diameter, in. [mm] (E_1) Handtight engagement
⅛	6	27	0.563 [14.3]	¾ [19]	0.3736 [9.49]
¼	8	18	0.719 [18.3]	1⅛ [29]	0.4916 [12.49]
⅜	10	18	0.875 [22.2]	1⅛ [29]	0.6270 [15.93]
½	15	14	1.063 [27.0]	1½ [38]	0.7784 [19.77]
¾	20	14	1.313 [33.4]	1 9/16 [40]	0.9889 [25.12]
1	25	11½	1.576 [40.0]	1 15/16 [49]	1.2386 [31.46]
1¼	32	11½	1.900 [48.3]	2 [50]	1.5834 [40.22]
1½	40	11½	2.200 [55.9]	2 [50]	1.8223 [46.29]
2	50	11½	2.750 [69.8]	2 1/16 [52]	2.2963 [58.33]
2½	65	8	3.250 [82.5]	3 1/16 [78]	2.7622 [70.16]
3	80	8	4.000 [101.6]	3 3/16 [81]	3.3885 [86.07]
3½	90	8	4.625 [117.5]	3 5/16 [84]	3.8888 [98.78]
4	100	8	5.000 [127.0]	3 7/16 [87]	4.3871 [111.43]
5	125	8	6.296 [159.9]	3 11/16 [94]	5.4493 [138.41]
6	150	8	7.390 [187.7]	3 15/16 [100]	6.5060 [165.25]
		Outside diameter tolerances:	For NPS 1½ [DN 40] and under		+0.015 in. [0.4 mm] −0.031 in. [0.8 mm]
			For NPS 2 [DN 50] and over		±1 %

TABLE 4 Coupling Thread Dimensions—Taper-Tapped (NPT) Recessed for Extra-Strong and Double-Extra-Strong Pipe (Dimensions conform to Line Pipe Couplings in accordance with API 5L)[A]

NPS Designator	DN Designator	Threads/in.	Outside diameter, in. [mm] W	Coupling min length, in. [mm] N_L	Pitch diameter in. [mm] (E_1) Handtight engagement
⅛	6	27	0.563 [14.3]	1¹⁄₁₆ [27]	0.3736 [9.49]
¼	8	18	0.719 [18.3]	1⅝ [41]	0.4916 [12.49]
⅜	10	18	0.875 [22.2]	1⅝ [41]	0.6270 [15.93]
½	15	14	1.063 [27.0]	2⅛ [54]	0.7784 [19.77]
¾	20	14	1.313 [33.4]	2⅛ [54]	0.9889 [25.12]
1	25	11½	1.576 [40.0]	2⅝ [67]	1.2386 [31.46]
1¼	32	11½	2.054 [52.2]	2¾ [70]	1.5834 [40.22]
1½	40	11½	2.200 [55.9]	2¾ [70]	1.8223 [46.29]
2	50	11½	2.875 [73.0]	2⅞ [73]	2.2963 [58.33]
2½	65	8	3.375 [85.7]	4⅛ [105]	2.7622 [70.16]
3	80	8	4.000 [101.6]	4¼ [108]	3.3885 [86.07]
3½	90	8	4.625 [117.5]	4⅜ [111]	3.8888 [98.78]
4	100	8	5.200 [132.1]	4½ [114]	4.3871 [111.43]
5	125	8	6.296 [159.9]	4⅝ [117]	5.4493 [138.41]
6	150	8	7.390 [187.7]	4⅞ [124]	6.5060 [165.25]
8	200	8	9.625 [244.5]	5¼ [133]	8.5000 [215.90]
10	250	8	11.750 [298.5]	5¾ [146]	10.6209 [269.77]
12	300	8	14.000 [355.6]	6⅛ [156]	12.6178 [320.49]
14	350	8	15.000 [381.0]	6⅜ [162]	13.8726 [352.36]
16	400	8	17.000 [431.8]	6¾ [171]	15.8758 [403.25]
18	450	8	19.000 [482.6]	7⅛ [181]	17.8750 [454.03]
20	500	8	21.000 [533.4]	7⅝ [194]	19.8703 [504.71]
	Outside diameter tolerances:	For NPS 1½ [DN 40] and under		+0.015 in. [0.4 mm] −0.031 in. [0.8 mm]	
		For NPS 2 [DN 50] and over		±1 %	
	Stand off tolerances:			±1 thread	

[A] Refer to API 5B for Threading and Gaging Practice.

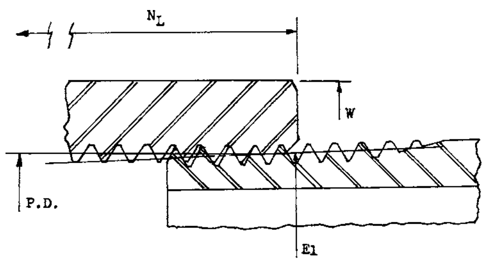

FIG. 1 Straight-Tapped Coupling and Pipe (See Table 2 for Coupling Dimensions)

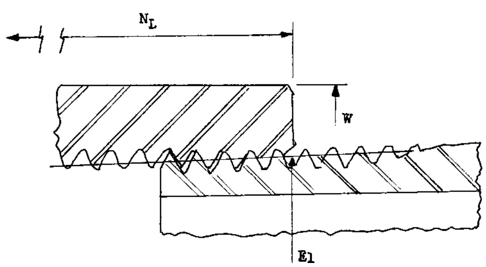

FIG. 2 Nonrecessed Taper-Tapped Coupling and Pipe (See Table 3 for Coupling Dimensions)

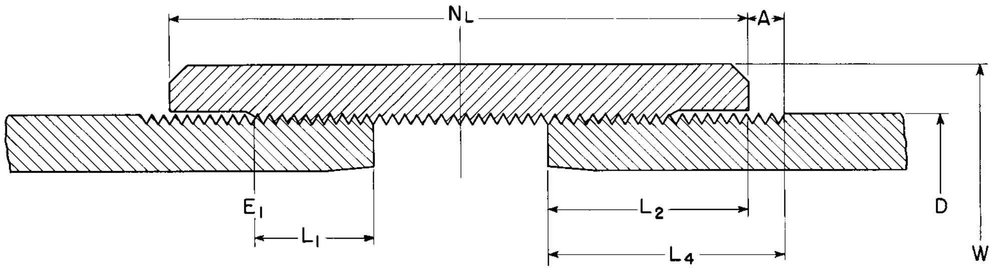

FIG. 3 Recessed Taper-Tapped Coupling and Pipe (See Table 4 for Coupling Dimensions)

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 865 – 03, that may impact the use of this specification. (Approved July 2006)

(*1*) Revised all applicable sections of the specification to include metrics, creating a dual unit specification.

Designation: A 860/A 860M – 00 (Reapproved 2005)

Standard Specification for Wrought High-Strength Low-Alloy Steel Butt-Welding Fittings[1]

This standard is issued under the fixed designation A 860/A 860M; 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 covers wrought high-strength low-alloy steel butt-welding fittings of seamless and electric fusion-welded construction covered by the latest revisions of ASME B16.9, ASME 16.28, and MSS-SP-75. Butt-welding fittings differing from these ASME and MSS standards shall be furnished in accordance with Supplementary Requirement S58 of Specification A 960/A 960M. These fittings are for use in high-pressure gas and oil transmission and distribution systems.

1.2 Optional supplementary requirements are provided for fittings when a greater degree of examination is desired. One or more of the supplementary requirements may be specified in the order.

1.3 This specification does not cover cast-welding fittings or fittings machined from castings.

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 this specification. Unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 960/A 960M Specification for Common Requirements for Wrought Steel Piping Fittings

2.2 *ASME Standards:*[3]

B16.9 Steel Butt-Welding Fittings

B16.28 Wrought Steel Buttwelding Short Radius Elbows and Returns

2.3 *AWS Standard:*

AWS 5.18 Specification for Carbon Steel Metals for Gas Shielded Arc Welding[4]

2.4 *ASME Boiler and Pressure Vessel Code:*[3]

Section V, Nondestructive Examination

Section VIII, Division 1, Pressure Vessels

Section IX , Welding and Brazing Qualifications

2.5 *MSS Standards:*[5]

MSS SP-25 The Standard Marking System of Valves, Fittings, Flanges and Unions

MSS-SP-75 Specification for High Test Wrought Butt-Welding Fittings

2.6 *American Society of Nondestructive Testing:*[6]

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

3. Ordering Information

3.1 In addition to the requirements of Specification A 960/A 960M, the following ordering information applies:

3.1.1 Grade Symbol,

3.1.2 Requirements for certification of test report.

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 960/A 960M, including any supplementary requirements that are indicated in the

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved Dec. 10, 2000. Published February 2001. Originally approved in 1986. Last previous edition approved in 1996 as A 860/A 860M – 96.

[2] 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.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

[4] Available from The American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.

[5] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602.

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

purchase order. Failure to comply with the general requirements of Specification A 960/A 960M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 960/A 960M, this specification shall prevail.

5. Materials and Manufacture

5.1 The material for fittings shall be fully killed fine-grain material made by a melting process that is intended to produce rounded, well dispersed, fine sulphide inclusions, that promote good notch toughness, assists in the resistance to hydrogen induced cracking, and for weldability suitable for field welding.

5.2 Starting materials shall consist of plate, sheet, forgings, forging quality bar, and seamless or fusion-welded tubular products with filler metal added. The chemical composition shall conform to Table 1.

5.3 A starting material that specifically requires the addition of any element beyond those listed in Table 1 is not permitted. This does not preclude the use of deoxidizers.

5.4 Starting material shall not require a preheat for field welding provided that the restrictions of ASME Boiler and Pressure Vessel Code, Section VIII, Paragraph UW-30 are complied with.

5.5 Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion, welding, machining, or by a combination of these operations.

5.6 All welds including welds in tubular products from which the fittings are made shall be:

5.6.1 Made by welders, welding operators, and welding procedures qualified under the provisions of ASME Boiler and Pressure Vessel Code, Section IX,

5.6.2 Heat treated in accordance with Section 6 of this specification, and

5.6.3 Radiographically examined throughout the entire length of each weld in accordance with Articles 1 and 2 of ASME Boiler and Pressure Vessel Code, Section V with acceptance limits in accordance with Paragraph UW-51 of ASME Boiler and Pressure Vessel Code, Section VIII.

5.7 The welded joints of the fittings shall be furnished in accordance with the requirements of Paragraph UW-35(a) of ASME Boiler and Pressure Vessel Code, Section VIII.

5.8 All butt-weld tees manufactured by cold-forming methods shall be liquid penetrant or magnetic particle examined by one of the methods specified in Supplementary Requirements S69 or S70 of Specification A 960/A 960M. This examination shall be performed in accordance with a written procedure and shall be performed after final heat treatment. Only the side wall area of the tees need be examined. This area is defined by a circle that covers the area from the weld bevel of the branch outlet to the center line of the body or run. Internal and external surfaces shall be examined when size permits accessibility. No cracks shall be permitted. Other imperfections shall be treated in accordance with 12.1 on finish. After the removal of any cracks, the tees shall be re-examined by the original method. Acceptable tees shall be marked with the symbol PT or MT, as applicable, to indicate compliance. NDE personnel shall be qualified in accordance with SNT-TC-1A.

5.9 All caps machined from bar stock shall be examined by liquid penetrant or magnetic particle in accordance with Supplementary Requirements S69 or S70 of Specification A 960/A 960M, and with personnel qualifications, acceptance criteria, and marking as in 5.8.

TABLE 1 Chemical Requirements

	Composition % Heat Analysis	
Carbon	0.20^A	All values are maximum unless a range is stated
Manganese	1.00–1.45	
Phosphorus	0.030	
Sulfur	0.010	
Silicon	0.15–0.40^B	
Nickel	0.50^C	
Chromium	0.30^C	
Molybdenum	0.25^C	
Copper	0.35^C	
Titanium	0.05	
Vanadium	0.10	
Columbium	0.04	
Vanadium plus Columbium	0.12	
Aluminum	0.06	

^{A} The carbon equivalent, as calculated by the following formula, shall not exceed 0.42 %:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

^{B} If vacuum carbon deoxidation is used, silicon shall not exceed 0.10 % by heat analysis and 0.12 % by product analysis.

^{C} The sum of Ni + Cr + Mo + Cu shall not exceed 1.0 %.

6. Heat Treatment

6.1 All fittings shall be furnished in the heat-treated condition. Fittings formed above the transformation temperature or upon which welding is performed, shall be cooled to below the lower critical temperature prior to heat treatment. Fittings shall subsequently be heat treated by normalizing, quenching, and tempering or stress relieving in accordance with Specification A 960/A 960M.

7. Chemical Composition

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

7.2 The steel shall not contain any unspecified elements for the ordered grade to the extent that it conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

7.3 Analysis of each heat of steel shall be made from a sample taken preferably during the pouring of the heat. The results shall conform to Table 1 for either heat or Specification A 960/A 960M for product analysis limits as applicable.

7.4 The fittings manufacturer shall make a product analysis per heat from either the starting material or from a fitting. The chemical composition thus determined shall conform to Table 1. The product analysis shall be the basis for rejection. For referee purposes, Test Methods, Practices, and Terminology A 751 shall apply.

7.5 The carbon equivalent of the base metal, as determined by the following formula, shall not exceed 0.42 % for the product analysis:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

7.6 Weld metal used in the construction of the fittings shall conform to the tensile and impact requirements of 9.4 and 8.1 after heat treatment in accordance with Section 6. A chemical analysis shall be performed on deposited weld metal for each heat of filler metal or, for submerged arc welding, each heat of filler metal and batch of flux. The weld metal shall be deposited in accordance with the qualified weld procedure.

7.7 Only the carbon content of the deposited weld-metal composition need comply with the requirements of Table 1. The nickel content of the deposited weld metal shall not exceed 1.0 %.

8. Notch Toughness Properties

8.1 The notch toughness properties of the fittings shall conform to the requirements listed in Table 2. The testing shall be performed in accordance with Test Methods and Definitions A 370. Full size Charpy, V-notch specimens shall be used whenever possible. Small size specimens shall be used only when the material thickness does not permit full size specimens. The impact specimens shall not be flattened after heat treatment. All base metal specimens shall be removed with the axis of the specimens longitudinal to the direction of primary metal flow. Weld-metal specimens shall be specimens with the axis transverse to the weld seam.

8.2 One set of impact tests (three specimens) shall be made to represent the base metal and one set (three specimens) to represent the weld metal on the same frequency as the tension tests.

8.3 The test temperature shall be −50°F [−46°C].

9. Tensile Requirements

9.1 The tensile properties of the fitting material shall conform to the requirements listed in Table 2.

9.2 Tension test specimens shall be taken from a fitting after final heat treatment or from a test piece of the same heat and nominal thickness that was heat treated in a furnace charge with the fittings they represent.

9.3 One tensile test is required for each heat of fittings of the same section thickness, and heat treated in either a continuous or batch-type furnace, controlled within a range of 50°F [28°C] and equipped with recording pyrometers.

9.4 In addition, fittings containing welds shall have one center-weld tension test made with the axis transverse to the weld seam for each heat of filler metal, or each heat of filler metal and batch of flux for submerged arc welds, for fittings of the same section thickness and heat treated in either a continuous or batch-type furnace controlled within a range of 50°F [28°C] and equipped with recording pyrometers. Only the ultimate tensile strength need meet the minimum requirement of Table 2.

10. Hardness Requirements

10.1 Fittings shall have a maximum hardness of 22 HRC (235 HB).

11. Dimensions

11.1 Dimensional requirements for NPS 14 and smaller butt-welding fittings are provided in ASME B16.9 and B16.28.

TABLE 2 Mechanical Requirements

Property	Grade					
	WPHY 42	WPHY 46	WPHY 52	WPHY 60	WPHY 65	WPHY 70
Yield strength, min[A] 0.2 % offset, ksi [MPa]	42 [290]	46 [315]	52 [360]	60 [415]	65 [450]	70 [485]
Tensile strength, ksi [MPa]	60 [415] −85 [585]	63 [435] − 88 [605]	66 [455] − 91 [625]	75 [515] − 100 [690]	77 [530] − 102 [705]	80 [550] −105 [725]
Elongation:						
Standard round specimen, or small-size proportional specimen, min, % in 4D	25	25	25	20	20	20
Rectangular specimen, for section thickness 5⁄16 in. [7.94 mm] and over, and for all small sizes tested in full section; min, % in 2 in. [50 mm].	32	32	32	28	28	28
Rectangular specimen for thickness less than 5⁄16 in. [7.94 mm]; min, % 2 in. [50 mm]. Width of specimen 1½ in. [40 mm].	[B]	[B]	[B]	[B]	[B]	[B]
Toughness:						
C_v energy absorption[C]; measured at −50°F [−46°C].						

Size, mm	Average/min, ft·lbs[J]	Lateral Expansion min, MLS[mm]
10× 10	30/25 [40/34]	25 [0.64]
10× 7.5	25/21 [34/28]	21 [0.53]
10× 5	20/17 [27/23]	13 [0.33]

[A] Actual yield strength shall not exceed specified minimum by more than 15 ksi [105 MPa].

[B] For each 1⁄32-in. [0.79 mm] decrease in section thickness below 5⁄16 in. [7.94 mm], a deduction of 1.5 % from the elongation value of specimens above 5⁄16 in. [7.94 mm] is permitted. When the section thickness lies between two values defined above, the minimum elongation value is determined by the following equation:

$$E = 48t + 15.00$$

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

[C] These requirements are intended to minimize fracture initiation. The requirements are not intended to give assurance against fracture propagation.

11.2 Dimensional requirements for butt-welding fittings larger than NPS 14 through NPS 48 are provided by MSS-SP-75.

11.3 Fittings of a size or shape differing from the standards in 11.1 and 11.2, but meeting all the other requirements of this specification, may be furnished in accordance with Supplementary Requirement S58 of Specification A 960/A 960M.

11.4 Fittings that do not have a thickness or yield strength, or both, that are equal to the mating pipe, are acceptable provided the welding end preparations comply with MSS-SP-75, Figs. 3(a), (b), and (c) and the fitting welding-end thickness is at least equal to the pipe wall thickness times the ratio of the specified minimum yield strength of the pipe and the minimum tested yield strength of the fitting.

12. Workmanship, Finish and Appearance

12.1 The requirements of Specification A 960/A 960M apply except as modified as follows: The wall thickness at all points shall be at least 93½ % of the specified nominal wall thickness, and the diameters at all points shall be within the specified limits.

12.2 When the removal of a surface discontinuity reduces the wall thickness below 93½ % of the specified nominal wall thickness at any point, the fitting shall be subject to rejection or to repair as provided in Section 13.

13. Repair by Welding (Base Metal)

13.1 Repair welding by the manufacturer is permissible in accordance with Specification A 960/A 960M and the following:

13.1.1 The deposited weld metal shall conform to the requirements of 7.4 and 7.5. Electrodes for the shielded metal-arc process shall be of the low-hydrogen type.

13.1.2 After repair welding, sections thicker than 1 in. [25 mm] also shall be radiographed in accrodance with 5.6.

13.1.3 All fittings repaired by welding shall be thermally treated after repair by either complete reheat treatment or post-weld heat treatment at least 50°F [28°C] below the tempering temperature if tempering has been performed.

13.1.4 Indications discovered by nondestructive examination shall, after reheat treatment, be again examined by the same NDE method as used in the original determination.

14. Hydrostatic Test

14.1 Hydrostatic testing is not required by this specification.

14.2 All fittings shall be capable of withstanding, after installation, without failure, leakage, or impairment of serviceability, a hydrostatic test pressure of 100 % based on minimum yield strength of the material grade, wall thickness, and outside diameter ordered in Section 3. The hydrostatic pressure shall be calculated in accordance with Barlow's equation:

$$P = 2S \cdot \frac{t}{D}$$

where:

P = hydrostatic pressure,
S = specific yield strength, min,
t = nominal wall thickness, and
D = outside diameter.

15. Rejection and Rehearing

15.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection shall be reported to the producer or supplier promptly in writing. In case of dissatisfaction with the results of the tests, the producer or supplier may make claim for a rehearing.

16. Certification

16.1 When requested by the purchaser, the manufacturer shall provide a certificate of compliance to this specification (including year date). In addition, if requested to provide test reports, the manufacturer shall also provide the following, when applicable:

16.1.1 Chemical analysis results, when (Section 7 and Table 1), base metal only, and

16.1.2 Tensile property results, (Section 9 and Table 2), the yield strength and ultimate strength in ksi, and elongation in percent for the base metal. Transverse-weld tensile strength shall be reported in ksi.

16.1.3 Impact test results, (Section 8 and Table 2), base metal and weld metal, specimen size, and test temperature,

16.1.4 Type heat treatment, (Section 6),

16.1.5 Radiographic examination results, and

16.1.6 Any supplemental testing required by the purchase order.

17. Product Marking

17.1 Identification marking shall consist of the Manufacturer's symbol or name (Note Note 1), specification number (year date not needed), grade symbol, size and nominal wall thickness or schedule, and heat code identification. In addition, quench and tempered fittings shall be marked with the symbol QT, and cold-formed tees shall be marked as prescribed in 5.8.

NOTE 1—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component complies with this specification.

17.2 Fittings that have been repaired by welding shall be marked with the letter W following the designation number.

17.3 Marking shall be by low-stress die stamps or interrupted dot stamps and shall be in accordance with MSS-SP-25.

17.4 If the impact test temperature is other than −50°F [−46°C], it shall be marked on the fitting.

17.5 If extra yield strength or wall thickness is used in a compensatory manner as described in 11.4 of this specification, the fitting shall be marked with both the minimum wall measured at the welding ends of the fitting and the actual yield and specified yield as illustrated in the following:

Manufacturer	Designation	$\frac{\textit{Actual YS}}{\textit{Specified YS}}$	Diameter
MNFR	AXXX	$\frac{Z}{Y}$	16
Specified wall	Actual wall	Heat code	Heat treatment
0.95	0.98	QQR	QT

where:

Z = actual yield strength, and
Y = specified minimum yield strength.

17.6 *Bar Coding*—In addition to the requirements in 17.1, 17.2, 17.3, 17.4, and 17.5, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 high-strength low-alloy steel; pipe fittings; steel; piping applications; pressure-containing parts

Designation: A 858/A 858M – 07

Standard Specification for Heat-Treated Carbon Steel Fittings for Low-Temperature and Corrosive Service[1]

This standard is issued under the fixed designation A 858/A 858M; 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 covers heat-treated wrought carbon steel piping fittings with lowered carbon content of seamless and electric fusion-welded construction covered by the latest revisions in ASME B16.9, ASME B16.11, ASME B16.28, MSS-SP-75, MSS-SP-79, MSS-SP-83, or MSS-SP-95. Fittings differing from these ASME and MSS standards shall be furnished in accordance with Supplementary Requirement S58 of Specification A 960/A 960M. These fittings are for use in pressure components where inherent notch toughness and optimum sulfide-cracking resistance are required, such as oil and gas industry piping and distribution systems.

1.2 Optional supplementary requirements are provided for fittings when a greater degree of examination is desired. One or more of the supplementary requirements may be specified in the order.

1.3 This specification does not cover cast-welding fittings or fittings machined from castings.

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. Combining values from the two systems may result in nonconformance with this specification. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Unless the other specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A 960/A 960M, the following list of standards apply to this specification.

2.2 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 960/A 960M Specification for Common Requirements for Wrought Steel Piping Fittings

2.3 *ASME Standards:*[3]

B16.9 Steel Butt-Welding Fittings

B16.11 Forged Steel Fittings, Socket Welding and Threaded

B16.28 Wrought Steel Buttwelding Short Radius Elbows and Returns

2.4 *MSS Standards:*[4]

MSS-SP-25 The Standard Marking System of Valves, Fittings, Flanges and Unions

MSS-SP-75 Specification for High Test Wrought Butt-Welding Fittings

MSS-SP-79 Socket Welding Reducer Inserts

MSS-SP-83 Steel Pipe Unions, Socket-Welding and Threaded

MSS-SP-95 Swage(d) Nipples and Bull Plugs

2.5 *ASME Boiler and Pressure Vessel Code:*

Section V Nondestructive Examination[5]

Section VIII Division 1, Pressure Vessels[5]

Section IX Welding and Brazing Qualifications

2.6 *American Society of Nondestructive Testing:*[6]

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

3. Ordering Information

3.1 In addition to the requirements of Specification A 960/A 960M, the following ordering information applies: requirements for certification of the test report.

4. General Requirements

4.1 Products furnished to this specification shall conform to the requirements of Specification A 960/A 960M, including any supplementary requirements that are indicated in the

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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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] 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.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

[4] Available from Manufacturers Standardization Society of the Valve and Fittings Industry, 1815 N. Fort Myer Drive, Arlington, VA 22209.

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

[6] 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.**

purchase order. Failure to comply with the general requirements of Specification A 960/A 960M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 960/A 960M, this specification shall prevail.

5. Materials

5.1 The material for fittings shall be fully killed fine-grain material made by a melting process that is intended to produce rounded, well dispersed, fine sulfide inclusions, that promote good notch toughness, assists in the resistance to hydrogen induced cracking, and for weldability suitable for field-welding.

5.2 Starting materials shall consist of plate, sheet, forgings, forging quality bar and seamless or fusion welded tubular products with filler metal added. The chemical composition shall conform to Table 1.

5.3 A starting material that specifically requires the addition of any element beyond those listed in Table 1 is not permitted. This does not preclude the use of deoxidizers.

5.4 Starting materials shall not require a preheat for field welding provided that the restrictions of *ASME Boiler and Pressure Vessel Code*, Section VIII, Paragraph UW-30 are complied with.

6. Manufacture

6.1 Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion welding, machining, or by a combination of these operations.

6.2 All welds including welds in tubular products from which the fittings are made shall be:

6.2.1 Made by welders, welding operators, and welding procedures qualified under the provisions of *ASME Boiler and Pressure Vessel Code*, Section IX,

6.2.2 Heat treated in accordance with Section 7 of this specification, and

6.2.3 Radiographically examined throughout the entire length of each weld in accordance with Articles 1 and 2 of *ASME Boiler and Pressure Vessel Code*, Section V with the acceptance limits in accordance with Paragraph UW-51 in Section VIII of that same code.

TABLE 1 Chemical Requirements

	Composition %	
	Heat Analysis	
Carbon	0.20	
Manganese	0.90–1.35	All values are maximum unless a range is shown
Phosphorus	0.030	
Sulfur	0.010	
Silicon	0.15–0.40[A]	
Nickel	0.50[B]	
Chromium	0.30[B]	
Molybdenum	0.20[B]	
Copper	0.35[B]	

[A] When vacuum carbon deoxidation is used, the silicon shall be 0.10 % maximum, and on product analysis shall not exceed 0.12 %.

[B] The combined total of nickel, chromium, molybdenum, and copper shall not exceed 1.0 %.

6.3 The welded joints of the fittings shall be furnished in accordance with the requirements of Paragraph UW-35(a) of *ASME Boiler and Pressure Vessel Code*, Section VIII.

6.4 All butt-weld tees manufactured by cold-forming methods shall be liquid-penetrant or magnetic-particle examined by one of the methods specified in Specification A 960/A 960M. This examination shall be performed in accordance with a written procedure and shall be performed after final heat treatment. Only the side wall area of the tees need be examined. This area is defined by a circle that covers the area from the weld bevel of the branch outlet to the center line of the body or run. Internal and external surfaces shall be examined when size permits accessibility. No cracks shall be permitted. Other imperfections shall be treated in accordance with Section 14 on finish. After the removal of any crack, the tees shall be re-examined by the original method. Acceptable tees shall be marked with the symbol PT or MT, as applicable, to indicate compliance. NDE personnel shall be qualified in accordance with SNT-TC-1A.

6.5 All caps machined from bar stock shall be examined by liquid penetrant or magnetic particle in accordance with Supplementary Requirement S69 or S70 with personnel qualifications, acceptance criteria and marking as in 5.4.

7. Heat Treatment

7.1 All fittings shall be furnished in the heat-treated condition. Fittings formed above the transformation temperature or upon which welding is performed, shall be cooled to below the lower criteria temperature prior to heat treatment. Fittings shall subsequently be heat treated by normalizing, quenching, and tempering or stress-relieving in accordance with Specification A 960/A 960M.

8. Chemical Composition Requirements

8.1 The chemical composition of the steel shall conform to the requirements prescribed in Table 1.

8.2 The steel shall not contain any unspecified elements for the ordered grade to the extent that it conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

8.3 An analysis of each heat of steel shall be made from a sample taken preferably during the pouring of the heat. The results shall conform to Table 1.

8.4 The fittings manufacturer shall make a product analysis per heat from either the starting material or from a fitting in accordance with Specification A 960/A 960M.

8.5 Weld metal used in the construction of the fittings shall conform to the tensile and impact requirements of 9.4 and 11.1 after heat treatment in accordance with Section 7. A chemical analysis shall be performed on deposited weld metal for each heat of filler metal or, for submerged arc welding, each heat of filler metal and batch of flux. The weld metal shall be deposited in accordance with the qualified weld procedure.

8.6 Only the carbon content of the deposited weld-metal composition need comply with the requirements of Table 1. The total nickel content of the deposited weld metal shall not exceed 1.0 %.

9. *Tensile Requirements* Tensile Requirements

9.1 The tensile properties of the fitting material shall conform to the requirements listed in Table 2.

9.2 Tension test specimens shall be taken from a fitting after final heat treatment or from a test piece of the same heat and nominal thickness that was heat-treated in a charge with the fittings it represents.

9.3 One tensile test is required for each heat of fittings of the same section thickness and heat treated in either a continuous- or batch-type furnace, controlled within a range of 50 °F [28 °C] and equipped with recording pyrometers.

9.4 In addition, fittings containing welds shall have one center-weld tension test made with the axis transverse to the weld seam for each heat of filler metal, or each heat of filler metal and batch of flux for submerged arc welds, for fittings of the same section thickness and heat treated in either a continuous or batch-type furnace controlled within a range of 50 °F [28 °C] and equipped with recording pyrometers. Only the ultimate tensile strength need meet the minimum requirements of Table 2.

10. Hardness Requirements

10.1 Fittings shall have a maximum hardness of 22 HRC (235 HB).

11. Notch Toughness Properties

11.1 The notch toughness properties of the fittings shall conform to the requirements listed in Table 2. The testing shall be performed in accordance with Methods and Definitions A 370. Full-size Charpy, V-notch, Type A specimens shall be used whenever possible. Small size specimens shall be used only when the material thickness does not permit full size specimens. The impact specimens shall not be flattened after heat treatment. All base metal specimens shall be removed with the axis of the specimens longitudinal to the direction of primary metal flow. Weld metal specimens shall have the axis transverse to the weld seam.

11.2 One set of impact tests (three specimens) shall be made to represent the base metal and one set of impact tests (three specimens) shall be made to represent the weld metal on the same frequency as the tension tests.

11.3 The test temperature shall be −50 °F [−46 °C].

TABLE 2 Mechanical Requirements

Yield strength, min, 0.2 % offset, ksi [MPa]	36 [250]
Tensile strength, min, ksi [MPa]	70 [485]-95 [655]
Elongation:	
Standard round specimen, or small-size proportional specimen, min, % in 4D	22
Rectangular specimen, for section thickness 5⁄16 in. [7.94 mm] and over, and for small sizes tested in full section; min, % in 2 in. [50 mm].	30
Rectangular specimen for section thickness less than 5⁄16 in. [7.94 mm]; min, % in 2 in. [50 mm]. Width of specimen 1½ in. [40 mm].	A
Reduction of area (round specimen only); min, %.	40
Toughness:	
C_v energy absorption[B]; measured at −50 °F [−46 °C]:	
Specimen size, mm	Average/min, ft·lbs [J]
10 × 10	20/16 [27/22]
10 × 7.5	17/13 [23/18]
10 × 5	13/11 [18/15]

[A] For each 1⁄32 in. [0.79 mm] decrease in section thickness below 5⁄16 in. [7.94 mm] a deduction 1.5 % from the 30 % shown above is permitted. Where the section thickness lies between two values defined above, the minimum elongation value is determined by the following equation:

$$E = 48t + 15.00$$

where:

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

[B] These requirements are intended to minimize fracture initiation. The requirements are not intended to give assurance against fracture propagation.

12. Dimensions

12.1 Dimensional requirements for NPS 14 and smaller fittings are provided by ASME B16.9, B16.11, B16.28, MSS-SP-79, MSS-SP-83, or MSS-SP-95.

12.2 Dimensional requirements for fittings larger than NPS 14 up through NPS 48 are provided in MSS-SP-75, except as modified by 12.3

12.3 Fittings of a size or shape differing from the standards in 12.1 and 12.2 but meeting all the other requirements of this specification, may be furnished in accordance with Supplementary Requirement S58 of Specification A 960/A 960M.

13. Finish and Appearance

13.1 See Specification A 960/A 960M for specific requirements.

14. Repair by Welding (Base Metal)

14.1 Repair welding, by the manufacturer, is permissible in accordance with Specification A 960/A 960M and the following:

14.1.1 The deposited weld metal shall conform to the requirements of 8.5 and 8.6. Electrodes for the shielded metal-arc process shall be of the low-hydrogen type.

14.1.2 Sections thicker than 1 in. [25 mm] shall also be radiographed after repair welding in accordance with 6.2.

14.1.3 All fittings repaired by welding shall be thermally treated after repair by either complete reheat treatment or post-weld heat treatment at least 50 °F [28 °C] below the tempering temperature if tempering has been performed.

14.1.4 Indications discovered by nondestructive examination shall, after heat treatment, be again examined by the same NDE method as used in the original determination.

14.1.5 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

15. Hydrostatic Test

15.1 Hydrostatic testing is not required by this specification.

15.2 Every fitting shall be capable of withstanding without failure, leakage, or impairment of serviceability, a hydrostatic test pressure of 1½ times its pressure rating or 1½ times the piping design pressure.

16. Rejection and Rehearing

16.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection shall be reported to the producer or supplier promptly in writing. In case of dissatisfaction with the results of the tests, the producer or supplier may make claim for a rehearing.

17. Certification

17.1 When requested by the purchaser, the manufacturer shall provide a certificate of compliance to this specification (including year date). In addition, if requested to provide test reports, the manufacturer shall also provide the following, where applicable:

17.1.1 Chemical analysis results, (Section 8 and Table 1), base metal only, and

17.1.2 Tensile property results, (Section 9 and Table 2), including the yield strength and tensile strength in ksi, and elongation and reduction of area in percent for the base metal. Transverse-weld tensile strength shall be reported in ksi.

17.1.3 Impact test results, (Section 11 and Table 2), base metal and weld metal, report specimen size and test temperature, and

17.1.4 Type heat treatment, (Section 7),

17.1.5 Radiographic examination results, and

17.1.6 Any supplemental testing required by the purchase order.

18. Product Marking

18.1 Identification marking shall consist of the manufacturer's symbol or name (See Note 1), specification number (year date not needed), size, and nominal wall thickness or schedule, and heat code identity. In addition, quenched and tempered fittings shall be marked with the symbol QT, and cold-formed tees shall be marked as prescribed in 6.4.

NOTE 1—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component complies with this specification.

18.2 Fittings that have been repaired by welding shall be marked with the letter W following the designation number.

18.3 Marking shall be by low-stress die stamps or interrupted dot stamps and shall be in accordance with MSS-SP-25.

18.4 If the impact test temperature is other than −50 °F [−46 °C], the impact test temperature shall be marked on the fitting.

18.5 *Bar Coding*—In addition to the requirements in 18.1, 18.2, 18.3, and 18.4, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

19. Keywords

19.1 corrosive service applications; pipe fittings–steel; piping applications; pressure containing parts; temperature service applications–low

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 858/A 858M – 06, that may impact the use of this specification. (Approved March 1, 2007)

(*1*) Added reference to MSS-SP-83 and MSS-SP-95 to 1.1 and 12.1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 858/A 858M – 00(2005), that may impact the use of this specification. (Approved March 1, 2006)

(*1*) Revised the metric value for tensile strength in Table 2.

Designation: A 847/A 847M – 05

Standard Specification for Cold-Formed Welded and Seamless High-Strength, Low-Alloy Structural Tubing with Improved Atmospheric Corrosion Resistance[1]

This standard is issued under the fixed designation A 847/A 847M; 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 covers cold-formed welded and seamless high-strength, low-alloy round, square, rectangular, or special shaped structural tubing for welded, riveted, or bolted construction of bridges and buildings and for general structural purposes where high strength and enhanced atmospheric corrosion resistance are required (Note 1). The atmospheric corrosion resistance of this steel in most environments is substantially better than carbon steel with or without copper addition (Note 2). When properly exposed to the atmosphere, this steel can be used bare (unpainted) for many applications. When this steel is used in welded construction, the welding procedure shall be suitable for the steel and the intended service.

1.2 This tubing is produced in welded sizes with a maximum periphery of 64 in. [1626 mm] and a maximum wall of 0.625 in. [15.9 mm], and in seamless with a maximum periphery of 32 in. [813 mm] and a maximum wall of 0.500 in. [12.7 mm]. Tubing having other dimensions may be furnished provided such tubing complies with all other requirements of this specification.

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 is to be used independently of the other, without combining values in any way.

NOTE 1—Products manufactured to this specification may not be suitable for those applications where low temperature notch toughness properties may be important, such as dynamically loaded elements in welded structures, etc.

NOTE 2—For methods of estimating the atmospheric corrosion resistance of low alloy steels see Guide G 101 or actual data.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

G 101 Guide For Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels

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 ASTM specification number,

3.1.2 Quantity (feet, metres, or number of lengths),

3.1.3 Name of material (cold-formed tubing),

3.1.4 Method of manufacture (welded or seamless),

3.1.5 Size (outside diameter and nominal wall thickness for round tubing and the outside dimensions and nominal wall thickness for square and rectangular tubing),

3.1.6 Length (specific or random, see 10.3),

3.1.7 End condition (see 14.2),

3.1.8 Burr removal (see 14.2),

3.1.9 Certification (see Section 17),

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved October 1, 2005. Published November 2005. Originally approved in 1985. Last previous edition approved in 2003 as A 847 – 99a(2003).

[2] 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.

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

3.1.10 End use, and
3.1.11 Special requirements.

4. Process

4.1 The steel shall be made by one or more of the following processes: open hearth, basic oxygen, or electric furnace.

5. Manufacture

5.1 The tubing shall be made by a welded or seamless process.

5.2 Welded tubing shall be made from flat-rolled steel by the electric-resistance welding or electric-fusion welding process. The longitudinal butt joint shall be welded across its thickness in such a manner that the structural design strength of the tubing section is assured.

5.2.1 Structural tubing welded by the electric-resistance method is normally furnished without removal of inside flash.

5.3 The tubing may be stress relieved or annealed, as is considered necessary by the tubing manufacturer, to conform to the requirements of this specification.

6. Chemical Composition

6.1 The choice and use of alloying elements combined with carbon, manganese, phosphorus, sulphur, and copper shall be within the limits prescribed in Section 7 to give the mechanical properties prescribed in Table 1 and to provide the atmospheric corrosion resistance of 1.1. The choice and use of these elements shall be made by the manufacturer and included and reported in the heat analysis to identify the type of steel applied. Elements commonly added include chromium, nickel, silicon, vanadium, titanium, and zirconium. For Specification A 847 material, the atmospheric corrosion-resistance index, calculated on the basis of the chemical composition of the steel as described in Guide G 101, shall be 6.0 or higher.

NOTE 3—The user is cautioned that the Guide G 101 predictive equation for calculation of an atmospheric corrosion-resistance index has been verified only for the composition limits stated in that guide.

7. Heat Analysis

7.1 Each heat analysis shall conform to the requirements given in Table 2 for heat analysis.

8. Product Analysis

8.1 The tubing shall be capable of comforming to the requirements given in Table 2 for product analysis.

8.2 If product analyses are made, they shall be made using test specimens taken from two lengths of tubing from each lot of 500 lengths, or a fraction thereof, or two pieces of flat-rolled stock from each lot of a corresponding quantity of flat-rolled stock. Methods and practices relating to chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751. Such product analyses shall conform to the requirements specified in Table 2 for product analysis.

8.3 If both product analyses representing a lot fail to conform to the specified requirements, the lot shall be rejected.

8.4 If only one product analysis representing a lot fails to conform to the specified requirements, product analyses shall be made using two additional test specimens taken from the lot. Both additional product analyses shall conform to the specified requirements or the lot shall be rejected.

9. Tensile Requirements

9.1 The material, as represented by the test specimen, shall conform to the tensile property requirements prescribed in Table 1.

10. Permissible Variations and Dimensions

10.1 *Outside Dimensions*:

10.1.1 *Round Structural Tubing*—The outside diameter shall not vary from the specified outside diameter by more than ± 0.5 %, rounded to the nearest 0.005 in. [0.1 mm], for specified outside diameters 1.900 in. [48.3 mm] and smaller; ± 0.75 %, rounded to the nearest 0.005 in., for specified outside diameters 2 in. [50 mm] and larger. The outside diameter measurements shall be made at positions at least 2 in. [50 mm] from either end of the tubing.

10.1.2 *Square and Rectangular Structural Tubing*—The specified dimensions, measured across the flats at a position at least 2 in. [50 mm] from either end of the tubing and including an allowance for convexity or concavity, shall not exceed the plus and minus tolerances shown in Table 3.

10.2 *Wall Thickness*—The minimum wall thickness at any point of measurement on the tubing shall be not more than 10 % less than the specified wall thickness. The maximum wall thickness, excluding the weld seam of welded tubing, shall be not more than 10 % greater than the specified wall thickness.

TABLE 1 Tensile Requirements for Round and Shaped Tubing

Tensile strength, min, psi [MPa]	70 000 [485]
Yield strength, min, psi [MPa]	50 000 [345]
Elongation in 2 in. or [50 mm] min, %	19[A]

[A] Applies to specified wall thicknesses 0.120 in. [3.0 mm] and over. For lighter wall thicknesses, elongation shall be by agreement with the manufacturer.

TABLE 2 Chemical Requirements

Elements	Heat Analysis	Product Analysis
Carbon, max	0.20	0.24
Manganese, max	1.35	1.40
Phosphorus, max	0.15	[A]
Sulphur, max	0.05	0.06
Copper, min	0.20[B]	0.18[B]

[A] Because of the degree to which phosphorus segregates, product analysis for this element is not technologically appropriate for rephosphorized steels unless misapplication is clearly indicated.

[B] If chromium and silicon contents are each 0.50 minimum, then the copper minimums do not apply.

TABLE 3 Outside Dimension Tolerances for Square and Rectangular Tubing

Largest outside dimension across flats, in. [mm]	Tolerance, ± in. [mm][A]
2½ [63.5] and under	0.020 [0.5]
Over 2½ [63.5] to 3½ [88.9], incl	0.025 [0.6]
Over 3½ [88.9] to 5½ [139.7], incl	0.030 [0.7]
Over 5½ [139.7]	1 %

[A] Tolerances include allowance for convexity or concavity. For rectangular sections, the tolerance calculated for the larger flat dimension shall also apply to the smaller flat dimension. This tolerance may be increased 50 % when applied to the smaller dimension if the ratio of the external sides is in the range of 1.5 to 3, inclusive; the tolerance may be increased 100 % when the ratio exceeds 3.

The wall thickness on square and rectangular tubing is to be measured at the center of the flat.

10.3 *Length*—Structural tubing is normally produced in random mill lengths 5 ft [1.5 m] and over, in multiple lengths, and in specified mill lengths (see Section 3). When specified mill lengths are ordered, the length tolerance shall be in accordance with Table 4.

10.4 *Straightness*—The permissible variation for straightness of structural tubing shall be ⅛ in. times the number of feet [10.4 mm times the number of metres] of total length divided by 5.

10.5 *Squareness of Sides*—For square and rectangular structural tubing, adjacent sides may deviate from 90° by a tolerance of ± 2° maximum.

10.6 *Radius of Corners*—For square or rectangular structural tubing, the radius of any outside corner of the section shall not exceed three times the specified wall thickness.

10.7 *Twist*—The tolerances for twist, or variation with respect to axial alignment of the section, for square and rectangular structural tubing shall be as shown in Table 5. Twist is measured by holding down on a flat surface plate one end of a square or rectangular tube, with the bottom side of the tube parallel to the surface plate and either (*1*) noting the difference in height above the surface plate of the two corners at the opposite end of the bottom side of the tube, or (*2*) by measuring this difference on the heavier sections by a suitable measuring device. The difference in the height of the corners shall not exceed the values of Table 5. Twist measurements are not to be taken within 2 in. [50 mm] of either end of the product.

11. Special Shaped Structural Tubing

11.1 The dimensions and tolerances of special shaped structural tubing are available by inquiry and negotiation with the manufacturer.

12. Flattening Test

12.1 The flattening test shall be made on round structural tubing. A flattening test is not required for shaped structural tubing.

12.2 For welded round structural tubing, a specimen at least 4 in. [100 mm] in length shall be flattened cold between parallel plates in three steps, with the weld located at 90° from the line of direction of force. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces shall occur before the distance between the plates is less than two thirds of the original outside diameter of the tubing. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside or outside surfaces, except as provided for in 12.4, shall occur before the distance between the plates is less than one half of the original outside diameter of the tubing, but not less than five times the wall thickness of the tubing. During the third step, which is a test for soundness, continue the flattening until the specimen breaks or the opposite walls of the tubing meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

12.3 For seamless round structural tubing of 2⅜ in. [60.3 mm] specified outside diameter and larger, a section not less than 2½ in. [60 mm] in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, no cracks or breaks on the inside or outside surfaces, except as provided for in 12.4, shall occur before the distance between the plates is less than the value of *H*, calculated by the following equation:

$$H = (1 + e)t/(e + t/D)$$

where:
H = distance between flattening plates, in. [mm],
e = deformation per unit length, 0.06,
t = nominal wall thickness of tubing, in. [mm], and
D = actual outside diameter of tubing, in. [mm].

12.3.1 During the second step, which is a test for soundness, continue the flattening until the specimen breaks or the opposite walls of the tubing meet. Evidence of laminated or unsound material that is revealed during the entire flattening test shall be cause for rejection.

12.4 Surface imperfections not found in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with Section 14.

12.5 When low *D*-to- *t*-ratio tubulars are tested, the strain imposed due to geometry is unreasonably high on the inside surface at the 6 to 12 o'clock locations; therefore, cracks at these locations shall not be cause for rejection if the *D*-to-*t*-ratio is less than 10.

13. Test Methods

13.1 The tension specimens required by this specification shall conform to those described in the latest issue of Methods and Definitions A 370, Supplementary Requirements II.

13.2 The tension test specimens shall be taken longitudinally from a section of the finished tubing at a location at least 90° from the weld in the case of welded tubing, and shall not be flattened between gage marks. If desired, the tension tests may be made on the full section of the tubing; otherwise, a

TABLE 4 Specified Mill Length

	Tolerances for Structural Tubing			
	22 ft [6.7 m] and under		Over 22 ft [6.7 m]	
	Over	Under	Over	Under
Length tolerance for specified mill length, in. [mm]	½ [12.7]	¼ [6.4]	¾ [19.0]	¼ [6.4]

TABLE 5 Twist Tolerances for Square and Rectangular Structural Tubing

Specified dimension of longest side, in. [mm]	Maximum twist in the first 3 ft [1 m] and in each additional 3 ft	
	in.	mm
1½ [38.1] and under	0.050	1.4
Over 1½ [38.1] to 2½ [63.5], incl	0.062	1.7
Over 2½ [63.5] to 4 [101.6], incl	0.075	2.1
Over 4 [101.6] to 6 [152.4], incl	0.087	2.4
Over 6 [152.4] to 8 [203.2], incl	0.100	2.8
Over 8 [203.2]	0.112	3.1

longitudinal strip-test specimen as prescribed in Test Methods and Definitions A 370, Supplementary Requirements II, shall be used. The specimens shall have all burrs removed and shall not contain surface imperfections which would interfere with proper determination of the tensile properties of the metal.

13.3 The yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen, or to a total extension of 0.5 % of the gage length under load, shall be determined.

14. Workmanship, Finish, and Appearance

14.1 All tubing shall be free from defects and shall have a workmanlike finish.

14.1.1 Surface imperfections shall be classed as defects when their depth reduces the remaining wall thickness to less than 90 % of the specified nominal wall thickness.

14.1.2 Surface imperfections such as handling marks, light die or roll marks, or shallow pits are not considered defects, provided the imperfections are removable within the minimum wall permitted. The removal of such surface imperfections is not required. Welded tubing shall be free of protruding metal on the outside surface of the weld seam.

14.1.3 Defects having a depth not in excess of 33⅓ % of the wall thickness may be repaired by welding, subject to the following conditions:

14.1.3.1 The defect shall be completely removed by chipping or grinding to sound metal.

14.1.3.2 The repair weld shall be made using a low hydrogen process.

14.1.3.3 The projecting weld metal shall be removed to produce a workmanlike finish.

14.2 The ends of structural tubing, unless otherwise specified, shall be finished square cut and the burr held to a minimum. The burr can be removed on the outside diameter, inside diameter, or both, as a supplementary requirement. When burrs are to be removed, it shall be specified on the purchase order.

15. Number of Tests

15.1 One tension test, as specified in Section 13, shall be made from a length of tubing representing each lot.

15.2 The flattening test, as specified in Section 12, shall be made on one length of round tubing from each lot.

15.3 The term "lot" applies to all tubes of the same nominal size and wall thickness which are produced from the same heat of steel.

16. Retests

16.1 If the results of the mechanical tests of any lot do not conform to all requirements of Sections 9 and 12, retests may be made on additional tubing of double the original number from the same lot. Each lot shall conform to the requirements specified or the tubing represented by the test is subject to rejection.

16.2 In case of failure on retest to meet the requirements of Sections 9 and 12, the manufacturer may elect to retreat, rework, or otherwise eliminate the condition responsible for failure. Thereafter, the material remaining from the lot originally represented may be tested and shall comply with all requirements of this specification.

17. Certification

17.1 If specified in the purchase order or contract, the manufacturer shall furnish to purchaser a certificate of compliance stating that the product was manufactured, sampled, tested, and inspected in accordance with this specification and any other requirements designated in the purchase order or contract, and was found to meet all such requirements. Certificates of compliance shall include the specification number and year of issue.

17.2 If specified in the purchase or contract, the manufacturer shall furnish to the purchaser test reports for the product shipped that contain the heat analyses and the results of the tension tests required by this specification and the purchase order or contract. Test reports shall include the specification number and year of issue.

17.3 A signature or notarization is not required on certificates of compliance or test reports; however, the documents shall clearly identify the organization submitting them. Notwithstanding the absence of a signature, the organization submitting the document is responsible for its content.

17.4 A certificate of compliance or test report printed from, or used in electronic form from, an electronic data interchange (EDI) shall be regarded as having the same validity as a counterpart printed in the certifying organization's facility. The content of the EDI transmitted document shall conform to any existing EDI agreement between the purchaser and the manufacturer.

18. Inspection

18.1 All tubing shall be subject to inspection at the place of manufacture to ensure conformance to the requirements of this specification.

19. Rejection

19.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method sections, the length may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

19.2 Tubing found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such tubing shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

20. Marking

20.1 Except as noted in 20.2, each length of structural tubing shall be legibly marked to show the following information: manufacturer's name, brand, or trademark and the specification number.

20.2 For structural tubing having a largest dimension of 4 in. [100 mm] or less, the information listed in 20.1 may be marked on a tag securely attached to the bundle.

20.3 *Bar Coding*—In addition to the requirements in 20.1 and 20.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

21. Packing, Marking, and Loading

21.1 When specified in the order or contract, packing, marking, and loading shall be in accordance with the procedures of Practices A 700.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 847 – 99a(2003), that may impact the use of this specification. (Approved October 1, 2005)

(*1*) Revised applicable paragraphs of Sections 1, 10, 12, and 20, as well as Table 1, Table 3, Table 4, and Table 5, to include rationalized SI units, creating a combined standard.

Designation: A 836/A 836M – 02 (Reapproved 2007)

Standard Specification for Titanium-Stabilized Carbon Steel Forgings for Glass-Lined Piping and Pressure Vessel Service[1]

This standard is issued under the fixed designation A 836/A 836M; 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 covers nonstandard as-forged fittings, valve components, and parts for glass-lined piping and pressure vessel service. Mechanical properties are certified on the basis of test material subjected to heat treatments to simulate glass-coating operations.

1.2 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:* [2]

A 788/A 788M Specification for Steel Forgings, General Requirements

A 961/A 961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

3. Ordering Information

3.1 Product furnished to this specification shall conform to the requirements of Specification A 961/A 961M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 961/A 961M constitutes non-conformance with this specification.

3.2 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the ordering information in Specification A 961/A 961M and the following:

3.2.1 Supplementary requirements, and

3.2.2 Additional requirements (see 10.1, 12.1, 12.2, and 12.3).

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 961/A 961M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 The material shall be forged by hammering, pressing, rolling, extruding, or upsetting, such that the finished product will be a forging as defined in the Terminology Section of Specification A 788/A 788M.

4.2 When specified in the order, the manufacturer shall submit for approval by the purchaser a sketch showing the shape of the rough forging before machining.

4.3 Forgings shall be protected against sudden or too rapid cooling from the rolling or forging while passing through the critical range.

4.4 Heat treatment of forgings is neither required nor prohibited. However, the test material for qualifying the forging or the welding procedure shall be heat treated to simulate glass-coating operations.

5. Chemical Composition

5.1 An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The chemical composition thus determined shall conform to the requirements in Table 1.

6. Mechanical Properties

6.1 The test material shall conform to the requirements as to tensile properties prescribed in Table 2.

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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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved March 1, 2007. Published April 2007. Originally approved in 1984. Last previous edition approved in 2002 as A 836/A 836M – 02.

[2] 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.

TABLE 1 Chemical Requirements

Element	Composition, %
Carbon, max	0.20
Manganese, max	0.90
Phosphorus, max	0.05
Silicon, max	0.35
Sulfur, max	0.05
Titanium, min	4× carbon content
Titanium, max.	1.00

TABLE 2 Tensile Requirements

	Class I
Tensile strength, min, ksi [MPa]	55 [380]
Yield strength,[A] min, ksi [MPa]	25 [175]
Elongation in 2 in. or 50 mm, min, %	22
Reduction of area, min, %	35

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

7. Number of Tests and Retests

7.1 One tension test shall be made from each heat.

7.2 If any test specimen is defectively machined, it may be discarded and another specimen substituted.

8. Retests

8.1 When one or more representative test specimens do not conform to specification requirements for the tested characteristic, only a single retest for each nonconforming characteristic may be performed to establish product acceptability. Retests shall be performed on twice the number of representative specimens that were originally nonconforming. When any retest specimen does not conform to specification requirements for the characteristic in question, the lot represented by that specimen shall be rejected, or the test material shall be heat treated or reheat-treated in accordance with 4.4, and tested in accordance with Sections 6 and 7.

9. Test Specimens

9.1 The test material to be used for qualifying the forgings shall be heat treated with the forgings represented by the test material, if the forgings are heat treated, then, the test material shall be normalized three times from a minimum temperature of 1550 °F [845 °C] prior to testing. This heat treatment simulates glass-coating operations.

10. Repair by Welding

10.1 Approval by the purchaser shall be required prior to weld repair.

10.2 The welded test plate used to qualify the procedure shall be normalized three times at 1550 °F [845 °C] prior to testing to simulate glass-coating operations.

10.3 The composition of the weld deposits shall be similar to the base metal and in accordance with the procedure qualification for the applicable material. Welding shall be accomplished with a weld procedure designed to produce low hydrogen in the weldment. Short-circuit gas metal arc welding is permissible only with the approval of the purchaser.

11. Rejection and Rehearing

11.1 Samples representing material rejected by the purchaser shall be preserved until disposition of the claim has been agreed upon by the manufacturer and the purchaser.

12. Certification

12.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. The specification designation included on test reports shall include year of issue and revision letter, if any.

12.2 When specified in the purchase order or contract, a report of the test results shall be furnished.

12.3 Upon request of the purchaser in the contract or order, a report of the test results and chemical analyses shall be furnished.

13. Marking of Forgings

13.1 Identification marks consisting of the manufacturer's symbol or name (Note), designation of service rating, this specification number, class, and size shall be legibly forged or stamped on each forging, and in such a position as not to injure the usefulness of the forgings.

13.2 *Bar Coding*—In addition to the requirements in 13.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

14. Keywords

14.1 carbon; pipe fittings; piping applications; pressure containing parts; pressure vessel service; steel; steel flanges; steel forgings; steel valves

Designation: A 822/A 822M – 04

Standard Specification for Seamless Cold-Drawn Carbon Steel Tubing for Hydraulic System Service[1]

This standard is issued under the fixed designation A 822/A 822M; 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 covers nominal wall thickness, seamless, cold-drawn carbon steel tubing intended for use in hydraulic systems and in other similar applications where forming operations require tight radius bending and flaring.

1.2 Tubing sizes and thicknesses usually furnished to this specification are ⅛ to 3½ in. [3.2 to 88.9 mm] in outside diameter and 0.035 to 0.134 in. [0.9 to 3.4 mm] inclusive, in nominal wall thickness. Tubing having other dimensions may be furnished, provided such tubing complies with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 Optional supplementary requirements are provided and, when desired, shall be so stated in the order.

1.5 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 shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *lot—for tension 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.

4. Ordering Information

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

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (seamless tubing),

4.1.3 Manufacture (cold-drawn),

4.1.4 Tube size (outside diameter and nominal wall thickness),

4.1.5 Length (specific or random),

4.1.6 Test report required (see Certified Test Report section in Specification A 450/A 450M),

4.1.7 Specification designation, and

4.1.8 End use of material.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the latest edition of Specification A 450, unless otherwise provided herein.

6. Manufacture

6.1 Tubes shall be made by the seamless process and shall be cold drawn to size.

7. Heat Treatment

7.1 Tubes shall be heated after the final cold working operation to a temperature of at least 1200°F [650°C].

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved March 1, 2004. Published March 2004. Originally approved in 1984. Last previous edition approved in 2000 as A 822–90 (2000).

[2] 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.

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

8. Chemical Composition

8.1 Steel shall conform to the chemical composition requirements prescribed in Table 1.

9. Mechanical Properties

9.1 *Tensile Properties*—Material shall conform to the tensile properties prescribed in Table 2.

9.2 *Hardness Requirements*—Finished tubes shall have a hardness not exceeding 65 HRB. The hardness test shall not be required on tubing having a nominal wall thickness of less than 0.065 in. [1.7 mm].

9.3 *Flattening Test*—A section of finished tubing, not less than 3 in. [75 mm] in length shall not crack or exhibit flaws when flattened between parallel plates to a distance equal to three times the tubing nominal wall thickness. Superficial ruptures resulting from minor surface imperfections shall not be considered cause for rejection.

10. Permissible Variations in Dimensions

10.1 Permissible variations in the outside diameter of the tubing shall not exceed the values given in Table 3.

10.2 Permissible variations in the wall thickness of the tubing shall not exceed ±10 % for tubing having 0.50 in. [12.7 mm] or larger nominal outside diameter or more than ±15 % for tubing having a smaller nominal outside diameter.

11. Workmanship, Finish, and Appearance

11.1 Finished tubes shall be free of scale but may have a superficial oxide film on the surfaces.

11.2 Finished tubes shall be reasonably straight and have smooth ends free of burrs. Tubes shall have a workmanlike finish and shall be free of surface imperfections that cannot be removed within the allowable wall tolerances. Removal of surface imperfections, such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern, will not be required provided they are within the allowable tolerances.

11.3 Finished tubes shall be protected both on the outside and the inside diameter to prevent corrosion in transit. If a corrosion preventive compound is applied, it shall be such that after normal storage periods it can be readily removed by cleaning.

TABLE 1 Chemical Requirements

Element	Composition, %
Carbon	0.18 max
Manganese	0.27 to 0.63
Phosphorus	0.048 max
Sulfur	0.058 max

TABLE 2 Tensile Requirements

Tensile strength, min., ksi [MPa]	45 [310]
Yield strength, min., ksi [MPa]	25 [170]
Elongation, in 2 in. [or 50 mm], min., %	35

TABLE 3 Tubing Outside Diameter Tolerances

Nominal Tubing Outside Diameter,[A] in. [mm]	Outside Diameter Tolerance, in. [mm]
Up to 1 [25]	±0.004 [0.10]
1 to 1½ [25 to 38]	±0.006 [0.15]
Over 1½ to 2 [38 to 50], inclusive	±0.008 [0.20]
Over 2 to 3½ [50 to 90], inclusive	±0.010 [0.25]

[A] The actual outside diameter shall be the average of the maximum and minimum outside diameters as determined at any one cross-section through the tubing.

12. Number of Tests

12.1 One tension test, flaring test, flattening test, and hardness test shall be made on each lot of tubes.

13. Hydrostatic Proof Test

13.1 Tubing supplied under this specification shall have been tested hydrostatically, with no evidence of failure or permanent deformation, at a pressure that will subject the material to a hoop stress of 20 000 psi [140 MPa]. Test pressures shall be determined as follows:

$$P = \frac{2TS}{D}$$

where:

D = outside diameter of tubing, in. [mm],
P = hydrostatic pressure, psi [MPa],
S = allowable stress = 20 000 psi [140 MPa], and
T = minimum wall thickness of tubing, in. [mm].

13.2 No tube shall be tested beyond a hydrostatic pressure of 5000 psi [35 MPa], unless so specified on the purchase order.

14. Packaging and Package Marking

14.1 Tubing shall be packaged or bundled in such a manner as to prevent damage in ordinary handling and transportation.

14.2 Tubing shall be identified by a tag with the name of the manufacturer, purchase order number, specification designation, and size.

15. Keywords

15.1 carbon; pressure-containing parts; seamless steel tube; steel tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order, in which event the necessary tests shall be made by the manufacturer prior to shipment of the tubing.

S1. Product Analysis

S1.1 Product analysis shall be made by the supplier from one tube per heat of steel. If the original test for product analysis fails, retests of two additional lengths of tubes shall be made. Both retests shall meet the requirements of this specification for the elements in question; otherwise, all remaining material in the heat shall be rejected or, at the option of the producer, each length of tube may be individually tested for acceptance. Lengths of tubes which do not meet the requirements of this specification shall be rejected.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 822–90 (2000)) that may impact the use of this standard.

(1) Revised standard text and tables to include rationalized SI units and create a combined standard.

Designation: A 815/A 815M – 07a

Standard Specification for Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings[1]

This standard is issued under the fixed designation A 815/A 815M; 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 covers two general classes, WP and CR, of wrought ferritic, ferritic/austenitic, and martensitic stainless steel fittings of seamless and welded construction covered by the latest revision of Specification A 960/A 960M. Fittings differing from these standards may be furnished in accordance with Supplementary Requirement S8.

1.1.1 Class WP fittings are subdivided into four subclasses: Classes WP-S, WP-W, WP-WX, and WP-WU. They are manufactured to the requirements of Specification A 960/A 960M, and they shall have pressure ratings compatible with 12.2. Class WP-S fittings are those manufactured from seamless product by a seamless method of manufacture (marked with class symbol WP-S); Class WP-W fittings are those which contain welds where the fitting fabrication or construction welds have been radiographed (marked with class symbol WP-W); and Class WP-WX fittings are those which contain welds where all welds have been radiographed (marked with class symbol WP-WX); and Class WP-WU fittings are those which contain welds where all welds have been ultrasonically tested (marked with class symbol WP-WU).

1.1.2 Class CR fittings are those manufactured to the requirements of MSS SP-43, and they shall have pressure ratings compatible with 12.3.

1.2 This specification does not apply to cast fittings.

1.3 Optional supplementary requirements are provided. When desired, one or more of these may be specified in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation [SI units], the material shall be furnished to inch-pound units.

1.5 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.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

A 960/A 960M Specification for Common Requirements for Wrought Steel Piping Fittings

E 165 Test Method for Liquid Penetrant Examination

2.2 *ASME Standards:*[3]

B16.9 Wrought Steel Butt-Welding Fittings

B16.11 Forged Steel Fittings, Socket-Welding and Threaded

2.3 *MSS Standards:*[4]

MSS SP-43 Standard Practice for Light Weight Stainless Steel Butt-Welding Fittings

MSS SP-79 Socket-Welding Reducer Inserts

MSS SP-83 Steel Pipe Unions, Socket-Welding and Threaded

MSS SP-95 Swage(d) Nipples and Bull Plugs

2.4 *ASME Boiler and Pressure Vessel Codes:*[3]

Section VIII Division I, Pressure Vessels

2.5 *ASNT Standard:*[5]

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] 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.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[4] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602, http://www.mss-hq.com.

[5] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

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

SNT-TC-1A(1984) Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

3. Common Requirements and Ordering Information

3.1 Material furnished to this specification shall conform to the requirements of Specification A 960/A 960M including any supplementary requirements that are indicated in the purchase order. Failure to comply with the common requirements of Specification A 960/A 960M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A 960/A 960M, this specification shall prevail.

3.2 Specification A 960/A 960M identifies the ordering information that should be complied with when purchasing material to this specification.

4. Materials

4.1 The material for fittings shall consist of forgings, bars, plates, or seamless or welded tubular products that conform to the chemical requirements in Table 1.

4.2 The steel shall be melted by one of the following processes:

4.2.1 Electric furnace (with separate degassing and refining optional),

4.2.2 Vacuum furnace, or

TABLE 1 Chemical Requirements

NOTE 1—Where an ellipsis (. . .) appears in this table, there is no requirement.

Grade[A]			Composition, %											
Grade WP	Grade CR	UNS	C, max	Mn[B]	P, max	S, max	Si, max	Ni[B]	Cr	Mo	Cu, max	N	Ti	Other
Ferritic Steels														
WP27	CR27	S44627	0.010	0.75	0.020	0.020	0.40	0.50	25.0–27.5	0.75–1.50	0.20	0.015 max	. . .	Cb 0.05–0.20
WP33	CR33	S44626	0.06	0.75	0.040	0.020	0.75	0.50	25.0–27.0	0.75–1.50	0.20	0.040 max	0.20–1.00 (7×(C+N)) min	. . .
WP429	CR429	S42900	0.12	1.0	0.040	0.030	0.75	0.50	14.0–16.0	. . .	. . .	. . .	. . .	. . .
WP430	CR430	S43000	0.12	1.00	0.040	0.030	1.00	0.50	16.0–18.0	. . .	. . .	. . .	. . .	. . .
WP430TI	CR430Ti	S43036	0.10	1.00	0.040	0.030	1.00	0.75	16.0–19.5	. . .	. . .	. . .	(5×C) min 0.75 max	. . .
WP446	CR446	S44600	0.20	1.50	0.040	0.030	0.75	0.50	23.0–27.0	. . .	. . .	0.25	. . .	. . .
Ferritic/Austenitic Steels														
WPS31803	CRS31803	S31803	0.030	2.00	0.030	0.020	1.0	4.5–6.5	21.0–23.0	2.5–3.5	. . .	0.08–0.20	. . .	. . .
WPS32101	CRS32101	S32101	0.040	4.0–6.0	0.040	0.030	1.00	1.35–1.70	21.0–22.0	0.10–0.80	0.10–0.80	0.20–0.25	. . .	. . .
WPS32750	CRS32750	S32750	0.030	1.20	0.035	0.020	0.8	6.0–8.0	24.0–26.0	3.0–5.0	0.5	0.24–0.32	. . .	. . .
WPS32950	CRS32950	S32950	0.030	2.00	0.035	0.010	0.60	3.5–5.2	26.0–29.0	1.00–2.50	. . .	0.15–0.35	. . .	. . .
WPS32760	CRS32760	S32760	0.030	1.00	0.030	0.010	1.00	6.0–8.0	24.0–26.0[C]	3.0–4.0[C]	0.50–1.00	0.20–0.30[C]	. . .	W 0.50–1.00
WPS39274	CRS39724	S32974	0.030	1.00	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.50–3.50[C]	0.20–0.80	0.24–0.32	. . .	W 1.50–2.50
WPS32550	CRS32550	S32550	0.04	1.50	0.040	0.030	1.00	4.5–6.5	24.0–27.0	2.9–3.9	1.50–2.50	0.10–0.25	. . .	. . .
WPS32205	CRS32205	S32205	0.030	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5	. . .	0.14–0.20	. . .	. . .
Martensitic Steels														
WP410	CR410	S41000	0.15	1.00	0.040	0.030	1.00	0.50 max	11.5–13.5	. . .	. . .	. . .	. . .	. . .
WPS41008	CRS41008	S41008	0.08	1.00	0.040	0.030	1.00	0.60	11.5–13.5	. . .	. . .	. . .	. . .	. . .
WPS41500	CRS41500	S41500	0.05	0.50–1.00	0.030	0.030	0.60	3.5–5.5	11.5–14.0	0.50–1.00	. . .	. . .	. . .	W 0.50–1.00

[A] Naming system developed and applied by ASTM International.
[B] Maximum unless otherwise indicated.
[C] % Cr + 3.3 × % Mo + 16 × % N = 40 min.

4.2.3 Electric furnace followed by vacuum or electroslag-consumable remelting.

4.3 If secondary melting is employed, the heat shall be defined as all ingots remelted from a primary heat.

5. Manufacture

5.1 *Forming*—Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion welding, machining or by combination of two or more of these operations. The forming procedure shall be so applied that it will not produce surface discontinuities deeper than 5 % of the specified nominal thickness of the fitting.

5.2 All classes of fittings shall be heat treated in accordance with Section 6.

5.3 Fittings ordered as Class WP-S shall be of seamless construction and shall meet all requirements of Specification A 960/A 960M.

5.4 Fittings ordered as Class WP-W shall meet the requirements of Specification A 960/A 960M and (*1*) shall have all welds made by the fitting manufacturer and all pipe welds made with the addition of filler metal radiographically examined throughout the entire length in accordance with Paragraph UW-51 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code; and (*2*) shall not require radiography of the starting pipe weld if the pipe was welded without the addition of filler metal. In place of radiographic examination, welds made by the fitting manufacturer may be ultrasonically examined in accordance with the code requirements stated in 5.6.

5.5 Fittings ordered as Class WP-WX shall meet the requirements of Specification A 960/A 960M and shall have all welds, whether made by the fitting manufacturer or the starting material manufacturer, radiographically examined throughout their entire length in accordance with Paragraph UW-51 of Section VIII, Division I of the ASME Boiler and Pressure Vessel Code. The radiography of welds for this class of fittings can be done either prior to or after forming at the option of the manufacturer.

5.6 Fittings ordered as Class WP-WU shall meet the requirements of Specification A 960/A 960M and shall have all welds, whether made by the fitting manufacturer or the starting material manufacturer, ultrasonically examined throughout their entire length in accordance with Appendix 12 of Section VIII, Division 1 of ASME Boiler and Pressure Vessel Code.

5.7 The radiography or ultrasonic examination for this class of fittings may be done at the option of the manufacturer, either prior to or after forming.

5.8 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

5.9 Fittings covered in Specification A 960/A 960M and ordered as CR shall meet the requirements of Specification A 960/A 960M and do not require nondestructive examination.

5.10 All classes of fittings shall have the welders, welding operators, and welded procedures qualified under the provisions of Specification A 960/A 960M except that starting pipe welds made without the addition of filler metal do not require such qualification.

5.11 All joints welded with filler metal shall be finished in accordance with the requirements of Paragraph UW-35 (a) of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code.

5.12 Fittings machined from bar shall be restricted to NPS 4 or smaller.

5.12.1 All caps machined from bar shall be examined by liquid penetrant in accordance with Practice E 165.

5.13 Weld buildup is permitted to dimensionally correct unfilled areas produced during cold forming of stub ends. Radiographic examination of the weld buildup shall not be required provided that all of the following steps are adhered to:

5.13.1 The weld procedure and welders or welding operators meet the requirements of 5.10,

5.13.2 Heat-treatment is performed after welding and prior to machining,

5.13.3 All weld surfaces are liquid penetrant examined in accordance with Appendix 8 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, and

5.13.4 Repair of areas in the weld is permitted, but 5.13.1, 5.13.2, and 5.13.3 must be repeated.

5.14 Stub ends may be produced with the entire lap added as weld metal to a straight pipe section provided the welding satisfies the requirements of 5.10 for qualifications and 6.2 for post weld heat treatment.

5.14.1 *Class WP-W*—Radiographic inspection of the weld is required (see 5.4).

5.14.2 *Class WP-WX*—Radiographic inspection of all welds is required (see 5.5).

5.14.3 *Class WP-WU*—Ultrasonic inspection of all welds is required (see 5.6).

5.14.4 *Class CR*—Nondestructive examination is not required (see 5.9).

5.15 Stub ends may be produced with the entire lap added by the welding of a ring, made from plate or bar of the same alloy grade and composition, to the outside of a straight section of pipe, provided the weld is double welded, is a full penetration joint, satisfies the requirements of 5.10 for qualifications and 6.2 for post weld heat treatment.

5.15.1 *Class WP-W*—Radiographic inspection of all welds, made with the addition of filler metal is required (see 5.4).

5.15.2 *Class WP-WX*—Radiographic inspection of all welds, made with or without the addition of filler metal, is required (see 5.5).

5.15.3 *Class WP-WU*—Ultrasonic inspection of all welds, made with or without the addition of filler metal, is required (see 5.6).

5.15.4 *Class CR*—Nondestructive examination is not required (see 5.9).

6. Heat Treatment

6.1 All fittings shall be heat treated in accordance with the requirements specified in Table 2.

6.2 All welding shall be done prior to the heat treatment specified in Table 2.

6.3 All fittings machined directly from forgings or bars (see 5.12), previously heat treated in accordance with the requirements specified in Table 2, need not be reheat treated.

TABLE 2 Heat Treatment

Stainless Steel	All WP and CR Grades	Temperature	Cooling	Tempering Temperature
Ferritic	All	≥ 1200 °F [650 °C]	As appropriate for grade	Not specified
Ferritic/Austenitic	S31803	1870–2010 °F [1020–1100 °C]	Water quench or rapidly cooled by other means	Not required
	S32101	1870 °F [1020 °C] min	Water quench or rapidly cooled by other means	Not required
	S32205	1870–2010 °F [1020–1100 °C]	Water quench	Not required
	S32750	1920–2060 °F [1025–1125 °C]	Water quench or rapidly cooled by other means	Not required
	S32760	2010–2085 °F [1100–1140 °C]	Water quench or rapidly cooled by other means	Not required
	S39274	1920–2060 °F [1025–1125 °C]	Water quench or rapidly cooled by other means	Not required
	S32550	1950–1975 °F [1065–1080 °C]	Water quench	Not required
	S32950	Not specified	Not specified	Not required
Martensitic	S41000	≥ 1200°F [650°C]	Not specified	Not specified
	S41008	>1200°F [650°C]	In still air as appropriate for grade	Not specified
	S41500	≥ 1750 °F [955 °C]	Air cool to ≤ 200 °F [95 °C] prior to any optional intermediate temper and prior to final temper.	1050–1150 °F [565–620 °C]

7. Chemical Composition

7.1 The chemical composition of each cast or heat shall be determined and shall conform to the requirements of the chemical composition for the respective grades of materials listed in Table 1. Methods and practices relating to chemical analyses required by this specification shall be in accordance with Methods, Practices, and Definitions A 751. Product analysis tolerances in accordance with Table 3 are applicable.

7.2 Except as listed below, in fittings of welded construction, the composition of the deposited weld shall conform to the same requirements as the base metal.

7.2.1 Welds on S32950 base metal shall be made with nominal 26 % Cr, 8 % Ni, 2 % Mo weld metal.

7.2.2 Welds on S31803 base metal shall conform to the same requirements as the base metal or shall be made with nominal 22 % Cr, 8 to 10 % Ni, 3 % Mo weld metal.

8. *Tensile Requirements* Tensile Requirements

8.1 The tensile properties of the fitting material shall conform to the requirements of Table 4. The testing and reporting shall be performed in accordance with Test Methods and Definitions A 370.

8.2 At least one tension test per heat shall be made on material representative of the fitting, including weld metal when filler metal is added, and in the same condition of heat treatment as the finished fitting it represents.

8.3 The fittings manufacturer shall perform a tensile test on material representative of the finished fitting. Records of the tensile test made on the starting material may be certification that the material of hot–finished fittings meets the tensile requirements of this specification provided the heat treatments are the same.

9. Hardness Requirements

9.1 Fittings shall not exceed the maximum hardness shown in Table 4.

10. Dimensions

10.1 The sizes, shapes, and dimensions of the fittings covered by ASME B16.9, ASME B16.11, MSS SP-43, MSS SP-79, MSS-SP-83, or MSS-SP-95 shall be as specified in those standards.

10.2 Fittings of size or shape differing from these standards, but meeting all other requirements of this specification, may be furnished in accordance with Supplementary Requirement S8.

11. Workmanship, Finish, and Appearance

11.1 Fittings supplied under this specification shall be examined visually. Selected typical surface discontinuities shall be explored for depth. The fittings shall be free from surface discontinuities that penetrate more than 5 % of the specified nominal wall thickness, except as defined in 11.3 and 11.4, and shall have a workmanlike finish.

11.2 Surface discontinuities deeper than 5 % of the specified nominal wall thickness, except as defined in 11.3 and 11.4, shall be removed by the manufacturer by machining or grinding to sound metal, and the repaired areas shall be well faired. The wall thickness at all points shall be at least 87½ % of the specified nominal wall thickness, and the diameters at all points shall be within the specified limits.

TABLE 3 Product Analysis Tolerances for Higher Alloy and Stainless Steels[A]

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	0.030, incl	0.005
	over 0.030 to 0.20, incl	0.01
Manganese	to 1.00, incl	0.03
	over 1.00 to 3.00, incl	0.04
	over 3.00 to 6.00	0.05
	over 6.00 to 10.00	0.06
Phosphorus	to 0.040, incl	0.005
Sulfur	to 0.030, incl	0.005
Silicon	to 1.00, incl	0.05
	over 1.00 to 1.40, incl	0.10
Chromium	over 4.00 to 10.00, incl	0.10
	over 10.00 to 15.00, incl	0.15
	over 15.00 to 20.00, incl	0.20
	over 20.00 to 27.50, incl	0.25
Nickel	to 1.00, incl	0.03
	over 1.00 to 5.00, incl	0.07
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 20.00, incl	0.15
	over 20.00 to 22.00, incl	0.20
Molybdenum	over 0.20 to 0.60, incl	0.03
	over 0.60 to 2.00, incl	0.05
	over 2.00 to 7.00, incl	0.10
Titanium	all ranges	0.05
Copper	to 0.50	0.03
Nitrogen	to 0.19, incl	0.01
	over 0.19 to 0.25	0.02
	over 0.25 to 0.35	0.03
	over 0.35 to 0.45	0.04
Columbium	0.05 to 0.20, incl	0.01
Tungsten	to 1.00	0.04

[A] This table does not apply to heat analysis.

TABLE 4 Tensile and Hardness Requirements

All WP and CR Grades	Yield Strength, min, ksi [MPa]	Tensile Strength,[A] ksi [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	HB max
Ferritic Steels:				
S44627	40 [275]	65 [450]–90 [620]	20.0	190
S44626	45 [310]	68 [470]–93 [640]	20.0	241
S42900	35 [240]	60 [415]–85 [585]	20.0	190
S43000	35 [240]	65 [450]–90 [620]	20.0	190
S43036	35 [240]	60 [415]–85 [585]	20.0	190
S44600	40 [275]	70 [485]–95 [655]	18.0	207
Ferritic/Austenitic Steels:				
S31803	65 [450]	90 [620]	20.0	290
S32101	65 [450]	94 [650]	30.0	290
S32205	65 [450]	95 [655]	20.0	290
S32750	80 [550]	116 [800]–140 [965]	15.0	310
S32760	80 [550]	109 [750]–130 [895]	25.0	270
S32950	70 [485]	100 [690]	15.0	290
S39274	80 [550]	116 [800]	15.0	310
S32550	80 [550]	110 [760]	15.0	302
Martensitic Steels:				
S41000	30 [205]	70 [485]–95 [655]	20.0	207
S41008	30[205]	60[415]	22.0	183
S41500	90 [620]	110 [760]–135 [930]	15.0	295

[A]Minimum unless otherwise indicated.

11.3 Surface checks (fish scale) deeper than 1⁄64 in. [0.4 mm] shall be removed.

11.4 Mechanical marks deeper than 1⁄16 in. [1.6 mm] shall be removed.

11.5 When the removal of a surface discontinuity reduces the wall thickness below 87½ % of the specified nominal wall thickness at any point, the fitting shall be subject to rejection or to repair as provided in 11.6.

11.6 *Repair by Welding*:

11.6.1 Repair welding, of the base metal by the manufacturer, is permissible for fittings made to the dimensional standards listed in 10.1 or for other standard fittings made for stock. Prior approval of the purchaser is required to repair special fittings made to the purchaser's requirements. Repair by welding shall neither exceed 10 % of the outside surface area of the fitting nor 33⅓ % of the nominal wall thickness.

11.6.2 The welding procedure and welders shall be qualified in accordance with Specification A 960/A 960M.

11.6.3 The alloy content (carbon, chromium, nickel, molybdenum, columbium, and titanium) of the deposited weld metal shall be within the same percentage range as permitted for the base metal. (**Warning**—When selecting the filler metal and welding procedure, consideration should be given to their effect on corrosion resistance in service.)

11.6.4 Surface discontinuities deeper than 5 % of the specified nominal wall thickness shall be removed by mechanical means or thermal cutting or gouging methods. Cavities prepared for welding shall be examined by the liquid penetrant method of Practice E 165. No cracks shall be permitted in the prepared cavities.

11.6.5 The weld repair shall be permanently identified with the welder's stamp or symbol in accordance with Specification A 960/A 960M.

11.6.6 Weld repair area(s) shall be blended uniformly to the base metal and shall be examined by liquid penetrant in accordance with Practice E 165. No cracks shall be permitted in the weld or surrounding ½ in. [13 mm] of base metal.

11.6.7 After weld repair, material shall be heat treated in accordance with Section 6.

11.7 The fittings shall be cleaned free of scale.

12. Hydrostatic Tests

12.1 Hydrostatic testing is not required by this specification.

12.2 Each fitting of Class WP shall be capable of withstanding without failure, leakage, or impairment of serviceability, a test pressure equal to that prescribed for the specified matching pipe or equivalent material.

12.3 Each fitting of Class CR, except tees covered in 12.3.1, shall be capable of withstanding without failure, leakage, or impairment of serviceability, a test pressure based on the ratings in MSS SP-43.

12.3.1 Class CR tees fabricated using intersection welds shall be capable of passing a hydrostatic test based on 70 % of the ratings in MSS SP-43.

13. Rejection

13.1 Unless otherwise specified, any rejection based on tests by the purchaser shall be reported to the manufacturer within 30 working days from the receipt of samples or test reports by the purchaser.

13.2 Each fitting that develops surface discontinuities deeper than 5 % of the specified nominal wall thickness in shop working or application operations may be rejected and the manufacturer so notified.

14. Rehearing

14.1 Test samples that represent fittings rejected by the purchaser shall be preserved for four weeks from the date of the rejection report. In case of dissatisfaction with the test results, the manufacturer may make claim for a rehearing within the period that the samples are preserved.

15. Certification

15.1 When requested by the purchaser, the manufacturer shall provide a certificate of conformance to this specification (including year date). In addition, if requested to provide test reports, the manufacturer shall also provide the following where applicable:

15.1.1 Chemical results, Section 7 (Table 1),

15.1.2 Tensile results, Section 8 (Table 4). Report yield strength and ultimate tensile strength in ksi [MPa], and elongation in percent,

15.1.3 Type of heat treatment, Section 6,

15.1.4 Starting material; plate, bar, pipe (specify welded or seamless), forging,

15.1.5 Seamless or welded construction,

15.1.6 Any supplemental testing required by the purchase order, and

15.1.7 Heat identification.

16. Test Reports

16.1 Test reports are required for all fittings covered by this specification. Each test report shall include the following information:

16.1.1 The year-date of the specification to which the fitting was furnished,

16.1.2 Heat number or serial number traceable to a heat number,

16.1.3 Chemical analysis for all starting materials,

16.1.4 Mechanical properties of all starting materials,

16.1.5 For construction with filler metal added, weld metal specification number,

16.1.6 For welded fittings, construction method, weld process, and procedure specification number,

16.1.7 Heat treatment type,

16.1.8 Results of all nondestructive examinations,

16.1.9 Results of all tests required by Supplementary Requirements and the order, and

16.1.10 Statement that the fitting was manufactured, sampled, tested, and inspected in accordance with the specification and was found to meet the requirements.

17. Keywords

17.1 corrosive service applications; ferritic/austenitic stainless steel; ferritic stainless steel; martensitic stainless steel; pipe fittings-steel; piping applications; pressure containing parts; stainless steel fittings

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements described below may be included in the purchaser's inquiry or in the order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirement details not fully described shall be agreed upon between the purchaser and the supplier.

S1. Product Analysis (Note S1.1)

S1.1 A product analysis shall be made for each heat of base metal and, if of welded construction, from each lot number of welding material of the fittings offered for delivery and shall conform to the requirements specified in Section 8.

NOTE S1.1—If the results of any of the tests specified in Supplementary Requirements S1, S2, or S3 do not conform to requirements, retests may be made at the manufacturer's expense on additional fittings or representative test pieces of double the original number from the same heat or lot as defined in Supplementary Requirements S1, S2, or S3, each of which shall conform to the requirements specified.

S2. Tension Test (Note S1.1)

S2.1 One tension test shall be made on one fitting or representative test piece (Note S2.1) per lot (Note S2.2) of fittings. If the fittings are of welded construction, the tension specimen shall include the weld and be prepared so that the weld is at the midlength of the specimen.

NOTE S2.1—Where the test specimen for the tension or intergranular corrosion bend test cannot be taken from a fitting due to size limitations, a representative test piece shall be obtained. The test piece shall be from the same lot it represents and shall have approximately the same amount of working. In addition, these pieces representing fittings manufactured from bars, plate, or forgings shall have a cross section equal to the greatest cross section of the fitting, and test pieces representing fittings manufactured from tubular products shall have a cross section approximately the same as that of the finished product. The test piece for fittings of welded construction shall be prepared to the same weld procedures and from the same heats of materials as the fittings it represents.

NOTE S2.2—A lot shall consist of all fittings of the same type, size, and wall thickness, manufactured from one heat of material (and, if fabrication welding is performed using one lot number of electrode or one heat of weld wire), and heat treated using the same heat treat cycle in either a continuous or batch-type furnace controlled within a range of 50 °F [28 °C] and equipped with recording pyrometers so that complete records of heat treatment are available.

S3. Intergranular Corrosion Bend Test (Note S1.1)

S3.1 An intergranular corrosion bend test shall be made on one fitting or representative test piece (Note S2.1) per lot (Note S2.2) of fittings. If the fittings are of welded construction, the bend specimen shall include the weld and be prepared so that the weld is at the midlength location of the specimen. Specimens containing a weld shall be bent so that the location of weld is at the point of maximum bend. The method of testing shall be in accordance with Practices A 262 or Practices A 763, as applicable.

S4. Ultrasonic Test

S4.1 Each fitting or the raw material from which each fitting is made shall be ultrasonically tested to determine its soundness. The method, where applicable, shall be in accordance with Practice A 388/A 388M. Acceptance limits shall be specified by the purchaser.

S5. Photomicrographs

S5.1 Photomicrographs at 100 diameters shall be made for information only of the actual base metal structure from one fitting as furnished in each lot. The photomicrographs shall be identified as to fitting size, wall thickness, lot identification, and heat. The definition of "lot" shall be as specified by the purchaser.

S6. Surface Finish

S6.1 Machined surfaces shall have a maximum roughness of 250 RMS (root-mean-square) or 6.3 µin. AA (arithmetical average). All other surfaces shall be suitable for ultrasonic testing.

S7. Liquid Penetrant Test

S7.1 All surfaces shall be liquid penetrant tested. The method shall be in accordance with Practice E 165.

S8. Special Fittings

S8.1 Partial compliance fittings of size and shape not conforming to the dimensional requirements of ASME B16.9, B16.11, or MSS SP-79 shall meet all other requirements of this specification. In addition to the marking required in Section 16, the grade designation symbol shall be followed by the symbol" S8."

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 815/A 815M – 07, that may impact the use of this specification. (Approved September 1, 2007)

(*1*) Added S32101 requirements to Table 1, Table 2, and Table 4.

(*2*) Corrected the Yield Strength for S32205, revised headings, and added new footnote A in Table 4.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 815/A 815M – 04, that may impact the use of this specification. (Approved April 1, 2007)

(*1*) Added MSS-SP-83 and MSS-SP-95 to 10.1 and Referenced Documents.

(*2*) Added Grade "WP" and "CR" to Ferritic/Austenitic Steels in Table 1.

(*3*) Added "All WP and CR Grades" to Tables 2 and 4.

Standard Specification for Cold-Worked Welded Austenitic Stainless Steel Pipe[1]

This standard is issued under the fixed designation A 814/A 814M; 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 covers two classes of flanged and cold-bending quality cold-worked straight-seam single or double welded austenitic steel pipe intended for high-temperature and general corrosive services.

NOTE 1—When the impact test criterion for a low-temperature service would be 15 ft·lbf [20 J] energy absorption or 15 mils [0.38 mm] lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades 304, 304L, and 347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by the Chemical Plant and Refinery Piping Code, ANSI B31.3 for service at temperatures as low as −425 °F [−250 °C] without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as −325 °F [−200 °C] without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10 %, are required to be impact tested under the rules of ASME Section VIII Division 1 when service temperatures are lower than −50 °F [−45 °C].

1.2 Grades TP304H, TP304N, TP316H, TP316N, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP316, TP321, TP347, and TP348, and are intended for high-temperature service.

1.3 Two classes of pipe are covered as follows:

1.3.1 *Class SW*—Pipe, single-welded with no addition of filler metal and

1.3.2 *Class DW*—Pipe, double-welded with no addition of filler metal.

1.4 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.5 Table 1 lists the dimensions of cold-worked single- or double-welded stainless steel pipe. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.6 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:* [2]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

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

E 112 Test Methods for Determining Average Grain Size

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

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *ASME Boiler and Pressure Vessel Code:*[3]

Section VIII Division 1, Pressure Vessels

2.3 *SAE Standard:*[4]

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

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, centimetres, or number of lengths),

[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.

Current edition approved Sept. 1, 2007. Published October 2007. Originally approved in 1983. Last previous edition approved in 2005 as A 814/A 814M – 05.

[2] 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.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[4] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

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

TABLE 1 Pipe Dimensions[A]

NOTE 1—For pipe sizes not listed and for pipe ordered to the "M" designation of this specification, the dimensions and tolerances shall be by agreement between the purchaser and producer.

NPS No.	Outside Diameter	Outside Diameter Tolerance	Schedule	Wall Thickness	Wall Tolerance
⅛	0.405	+0.004	10	0.049	±0.004
		−0.002	40	0.068	±0.005
			80	0.095	±0.006
¼	0.540	+0.005	10	0.065	±0.005
		−0.003	40	0.088	±0.006
			80	0.119.	±0.009
⅜	0.675	+0.006	10	0.065	±0.005
		−0.004	40	0.091	±0.006
			80	0.126	±0.010
½	0.840	+0.007	5	0.065	±0.005
		−0.005	10	0.083	±0.006
			40	0.109	±0.009
			80	0.147	±0.011
¾	1.060	+0.010	5	0.065	±0.005
		−0.007	10	0.083	±0.006
			40	0.113	±0.009
			80	0.154	±0.011
1	1.315	+0.010	5	0.065	±0.005
		−0.007	10	0.109	±0.009
			40	0.133	±0.011
			80	0.179	±0.014
1¼	1.660	+0.012	5	0.065	±0.005
		−0.0080	10	0.109	±0.009
			40	0.140	±0.011
			80	0.191	±0.014
1½	1.900	+0.015	5	0.065	±0.005
		−0.008	10	0.109	±0.009
			40	0.145	±0.011
			80	0.200	±0.015
2	2.375	+0.018	5	0.065	±0.005
		−0.008	10	0.109	±0.009
			40	0.154	±0.011
			80	0.218	±0.015
2½	2.875	+0.020	5	0.065	±0.005
		−0.009	10	0.120	±0.010
			40	0.203	±0.015
			80	0.276	±0.020
3	3.500	+0.025	5	0.083	±0.006
		−0.010	10	0.120	±0.010
			40	0.216	±0.015
			80	0.300	±0.020
3½	4.000	+0.025	5	0.083	±0.006
		−0.010	10	0.120	±0.010
			40	0.226	±0.018
			80	0.318	±0.020
4	4.500	+0.025	5	0.083	±0.006
		−0.010	10	0.120	±0.010
			40	0.237	±0.019
			80	0.337	±0.020

[A] All dimensions in inches.

3.1.2 Name of material (austenitic steel pipe),

3.1.3 Class (1.3). If not specified by the purchaser, the producer shall have the option to furnish either single-welded (SW) or double-welded (DW) pipe,

3.1.4 Grade (Table 2),

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

3.1.6 Length (specific or random) (Section 10),

3.1.7 End finish (Section on Ends of Specification A 999/A 999M),

3.1.8 Optional requirements (Section 9), (Supplementary Requirements S1 to S8),

3.1.9 Test report required (Section on Certification of Specification A 999/A 999M),

3.1.10 Specification designation, and

3.1.11 Special requirements or exceptions to the specification.

4. Materials and Manufacture

4.1 *Manufacture*:

4.1.1 The pipe shall be made by a machine-welding or an automatic-welding process, welding from one or both sides and producing full penetration welds with no addition of filler metal in the welding operation.

4.1.2 Weld repairs, with the addition of compatible filler metal, may be made to the weld joint in accordance with the requirements of the section on Repair by Welding of Specification A 999/A 999M.

4.1.3 Prior to final heat treatment of the pipe, the weld bead must be cold-worked by methods such as forging, planishing, drawing, swaging or bead rolling so as to obtain a flush condition on the inside and outside of the pipe. Undercuts shall be limited to shallow rounded depressions of less than 0.005 in. [0.127 mm] deep on either the inside or outside surface of the pipe with no encroachment of the minimum permitted wall thickness.

4.1.4 The pipe shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

4.2 *Heat Treatment*:

4.2.1 All pipe shall be furnished in the heat-treated condition. The heat-treatment procedure, except for H grades, S30815, N 08367 and S 31254, shall consist of heating the pipe to a minimum temperature of 1900 °F [1040 °C] and quenching in water or rapidly cooling by other means.

4.2.2 All H grades and S30815 shall be furnished in the solution-treated condition. The minimum solution treating temperature for Grades TP321H, TP347H, and TP348H shall be 2000 °F [1100 °C] and for Grades TP304H and TP316H, 1900 °F [1040 °C]. The minimum temperature for S30815 shall be 1920 °F [1050 °C].

4.2.3 The heat-treatment procedure for S 31254 shall consist of heating the pipe to a minimum temperature of 2100 °F [1150 °C] and quenching in water or rapidly cooling by other means.

4.2.4 The heat-treatment procedure for S31727 and S32053 shall consist of heating the pipe to a minimum temperature of 1975 to 2155 °F [1080 to 1180 °C] and quenching in water or rapidly cooling by other means.

4.2.5 UNS N 08367 shall be solution annealed from 2025 °F minimum followed by rapid quenching.

4.3 H grades and S30815 shall have a minimum grain size of 7 or coarser when measured in accordance with Test Methods E 112.

5. Chemical Composition

5.1 The steel shall conform to the chemical composition prescribed in Table 2.

5.2 When specified on the purchase order, a product analysis shall be supplied from one tube or coil of steel per heat. The product analysis tolerance of Specification A 480/A 480M shall apply.

TABLE 2 Chemical Requirements

Grade	UNS Designation[A]	Carbon, max[B]	Manganese, max[B]	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Titanium	Columbium plus Tantalum	Tantalum, max	Nitrogen[C]	Vanadium	Copper	Cerium
		Composition, %														
TP 304	S30400	0.08	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 304L	S30403	0.030[D]	2.00	0.045	0.030	1.00 max	8.0–13.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 304N	S30451	0.08	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .
TP 304LN	S30453	0.030	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .
TP 309Cb	S30940	0.08	2.00	0.045	0.030	1.00 max	12.0–16.0	22.0–24.0	. . .	. . .	10 × C min, 1.10 max	. . .	. . .	. . .	. . .	. . .
TP309S	S30908	0.08	2.00	0.045	0.030	1.00 max	12.0–15.0	22.0–24.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 310Cb	S31040	0.08	2.00	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	. . .	. . .	10 × C min, 1.10 max	. . .	. . .	. . .	. . .	. . .
TP 310S	S31008	0.08	2.00	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	0.75 max	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 316	S31600	0.08	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 316L	S31603	0.030[D]	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 316N	S31651	0.08	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00				0.10–0.16	. . .	. . .	. . .
TP 316LN	S31653	0.030	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .
TP 317	S31700	0.08	2.00	0.045	0.030	1.00 max	11.0–14.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP 317L	S31703	0.030	2.00	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S31727	0.030	1.00	0.030	0.030	1.00	14.5–16.5	17.5–19.0	3.8–4.5	. . .	. . .	. . .	0.15–0.21	. . .	2.8–4.0	. . .
. . .	S32053	0.030	1.00	0.030	0.010	1.00	24.0–26.0	22.0–24.0	5.0–6.0	. . .	. . .	. . .	0.17–0.22	. . .	. . .	. . .
TP 321	S32100	0.08	2.00	0.045	0.030	1.00 max	9.00–13.0	17.0–19.0	. . .	E	. . .	. . .	. . .	. . .	. . .	. . .
TP 321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–13.0	17.0–19.0	. . .	F	. . .	. . .	. . .	. . .	. . .	. . .
TP 347	S34700	0.08	2.00	0.045	0.030	1.00 max	9.00–13.0	17.0–19.0	. . .	. . .	G	. . .	. . .	. . .	. . .	. . .
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–13.0	17.0–19.0	. . .	. . .	H	. . .	. . .	. . .	. . .	. . .
TP 348	S34800	0.08	2.00	0.045	0.030	1.00 max	9.00–13.0	17.0–19.0	. . .	. . .	G	0.10	. . .	. . .	. . .	
TP 348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–13.0	17.0–19.0	. . .	. . .	H	0.10	. . .	. . .	. . .	. . .
TP XM-10	S21900	0.08	8.0–10.0	0.045	0.030	1.00 max	5.5–7.5	19.0–21.5	. . .	. . .	. . .	. . .	0.15–0.40	. . .	. . .	. . .
TP XM-11	S21903	0.04	8.0–10.0	0.045	0.030	1.00 max	5.5–7.5	19.0–21.5	. . .	. . .	. . .	. . .	0.15–0.40	. . .	. . .	. . .
TP XM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.5–18.5	17.0–19.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP XM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00 max	11.5–13.5	20.5–23.5	1.50–3.00	. . .	0.10–0.30	. . .	0.20–0.40	0.10–0.30	. . .	. . .
TP XM-29	S24000	0.08	11.5–14.5	0.060	0.030	1.00 max	2.3–3.7	17.0–19.0	. . .	. . .	. . .	. . .	0.20–0.40	. . .	. . .	. . .
. . .	S31254	0.020	1.00	0.030	0.010	0.80 max	17.5–18.5	19.5–20.5	6.0–6.5	. . .	. . .	. . .	0.18–0.22	. . .	0.50–1.00	. . .
. . .	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	. . .	. . .	. . .	. . .	0.14–0.20	. . .	. . .	0.03–0.08
	N08367	0.030	2.00	0.040	0.030	1.00 max	23.5-25.5	20.0-22.0	6.0-7.0	. . .	. . .	. . .	0.18-0.25	. . .	0.75 max	. . .

[A] New designation established in accordance with Practice E 527 and SAE J 1086.
[B] Maximum, unless otherwise indicated.
[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

[D] For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.044 in. [1 mm] in minimum wall thickness).
[E] The titanium content shall be not less than five times the carbon content and not more than 0.70 %.
[F] The titanium content shall be not less than four times the carbon content and not more than 0.70 %.
[G] The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.10 %.
[H] The columbium plus tantalum content shall be not less than eight times the carbon content and not more than 1.10 %.

6. Tensile Requirements

6.1 The tensile properties of the material shall conform to the requirements prescribed in Table 3.

7. Permissible Variations in Dimensions

7.1 *Specified Diameter*—The diameter at any point in each length of pipe shall be within the tolerance specified in Table 1.

7.2 *Alignment (Camber)*—Using a 3-ft [1.0-m] straightedge placed so that both ends are in contact with the pipe, the camber shall not be more than 0.030-in. [0.8-mm].

7.3 *Thickness*—The wall thickness at any point in the pipe shall be within the thickness tolerance specified in Table 3, except that for pipe in which the wall thickness exceeds 0.188-in. [4.8-mm] a weld reinforcement of up to 0.015-in. [0.38-mm] is permitted on the inside of the pipe.

8. Lengths

8.1 Pipe lengths shall be in accordance with the following regular practice.

TABLE 3 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
TP304L	S30403	70 [485]	25 [170]
TP316L	S31603	70 [485]	25 [170]
TP304	S30400	75 [515]	30 [205]
TP304H	S30409	75 [515]	30 [205]
TP309CB	S30940	75 [515]	30 [205]
TP309S	S30908	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP316	S31600	75 [515]	30 [205]
TP316H	S31609	75 [515]	30 [205]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
TP321	S32100	75 [515]	30 [205]
TP321H	S32109	75 [515]	30 [205]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21903	90 [620]	50 [345]
TPXM-15	S38100	75 [515]	30 [205]
TPXM-29	S24000	100 [690]	55 [380]
TPXM-19	S20910	100 [690]	55 [380]
TP304N	S30451	80 [550]	35 [240]
TP316N	S31651	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
TP316LN	S31653	75 [515]	30 [205]
...	S31254	94 [650]	44 [300]
...	S31727	80 [550]	36 [245]
...	S32053	93 [640]	43 [295]
...	S30815	87 [600]	45 [310]
. . .	N08367		
	t≤0.187	100 [690]	45 [310]
	t>0.187	95 [655]	45 [310]

8.1.1 Unless otherwise agreed upon, all sizes up to and including NPS 4 are available in a length up to 24 ft (Note 2) with the permissible range of 15 of 24 ft (Note 2).

NOTE 2—The 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.

8.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and not more than ¼ in. [6 mm] over that specified.

8.1.3 No jointers are permitted unless otherwise specified.

9. Workmanship, Finish, and Appearance

9.1 The finished pipes shall be free of injurious imperfections and shall have a workmanlike finish. Minor imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted in Section 9.

10. General Requirements

10.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

11. Examination of Double-Welded Pipe

11.1 Both ends of each double-welded (Class DW) pipe shall be visually examined to determine that complete fusion was attained between the two welds. In lieu of examining the ends of the pipe, this examination may be performed on cropped ends removed from both ends of each double welded pipe.

12. Mechanical Tests Required

12.1 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes.

NOTE 3—The term "lot", for mechanical tests, applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment (*1*) in a continuous heat-treatment furnace, or (*2*) in a batch-type heat-treatment furnace, equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] range, the larger of (*a*) Each 200 ft [60 m] or fraction thereof or, (*b*) That pipe heat treated in the same batch furnace charge.

12.2 *Flattening Test*—For material heat treated in a batch-type furnace, flattening tests shall be made of 5 % of the pipe from each heat-treated lot. For material heat treated by the continuous process, this test shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than two lengths of pipe.

12.2.1 For pipe where the diameter equals or exceeds NPS 10, a transverse-guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A 370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5 % of the lot shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

12.3 *Hydrostatic Test*—Each length of pipe shall be subjected to the hydrostatic test in accordance with Specification A 999/A 999M.

13. Product Marking

13.1 In addition to the marking specified in Specification A 999/A 999M, the marking shall include the manufacturer's identifying mark and double-welded pipe shall be identified with the mark (DW). For Grades TP304H, TP316H, TP321H, TP347H, TP348H, and S 30815, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

14. Keywords

14.1 austenitic stainless steel pipe; cold-worked pipe

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe NPS 5 and larger in nominal size, there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 in nominal size there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 6 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This applies only to pipe NPS 8 and larger in nominal size.

S2.2 If a specimen from any length fails to conform to the tensile properties specified, that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound welds and reasonably uniform material free of injurious laminations, cracks, and similar objectionable imperfections. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable imperfections, the length shall be rejected subject to the removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Eddy Current Examination

S5.1 Pipe soundness shall be determined through eddy-current examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S6. Ultrasonic Examination

S6.1 Pipe soundness shall be determined through ultrasonic examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S7. Corrosion Requirements

S7.1 *Boiling Nitric Acid Test*—Except for Grade TP 321, coupons representing finished pipe made of nonmolybdenum-bearing material (0.50 % and less molybdenum) shall meet the requirements Practice C of Practices A 262. The condition of the test specimens and the corrosion rates are as follows: Types 304L, 304LN, 347, and Type 348 shall be tested in the sensitized condition (heated for 1 h at 1240 °F [670 °C]) and the rate of penetration shall not exceed 0.0020 in. [0.05 mm]/month. All other nonmolybdenum-bearing types, except for Grade TP 321, shown in Table 2 shall be tested in the annealed and unsensitized condition and the rate of penetration when solution tested in accordance with Practice C shall not exceed 0.0015 in./month [0.038 mm/month].

S7.2 *Acidified Copper Sulfate Test*—Coupons representing finished pipe made of molybdenum-bearing material (over 0.50 % molybdenum) and Type 321 shall meet the requirements of Practice E of Practices A 262. The condition of the test specimen is as follows: Types 316L, 316LN, 317L and 321 shall be tested in the sensitized condition (heated for 1 h at 1240 °F [670 °C]). All molybdenum-bearing types shown in Table 2 shall be tested in the annealed and unsensitized condition. All specimens shall meet the requirements of the prescribed bend tests.

S8. Flange Test

S8.1 A section of pipe shall be capable of having a flange turned over at a right angle to the body of the pipe without cracking. The width of the flange shall be not less than 15 % of the oustide diameter of the pipe.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 814/A 814M – 05, that may impact the use of this specification. (Approved September 1, 2007)

(*1*) Added new 4.2.4 and renumbered subsequent paragraphs.

(*2*) Added S31727 and S32053 to Table 2 and Table 3.

Designation: A 813/A 813M – 07

Standard Specification for Single- or Double-Welded Austenitic Stainless Steel Pipe[1]

This standard is issued under the fixed designation A 813/A 813M; 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 covers two classes of fit-up and alignment quality straight-seam single- or double-welded austenitic steel pipe intended for high-temperature and general corrosive service.

NOTE 1—When the impact test criterion for a low-temperature service would be 15 ft·lbf [20 J] energy absorption or 15 mils [0.38 mm] lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades 304, 304L, and 347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by the Chemical Plant and Refinery Piping Code, ANSI B31.3 for service at temperatures as low as −425 °F [−250 °C] without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as −325 °F [−200 °C] without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10 %, are required to be impact tested under the rules of ASME Section VIII Division 1 when service temperatures are lower than −50 °F [−45 °C]

1.2 Grades TP304H, TP304N, TP316H, TP316N, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP316, TP321, TP347, and TP348, and are intended for high-temperature service.

1.3 Two classes of pipe are covered as follows:

1.3.1 *Class SW*—Pipe, single-welded with no addition of filler metal and

1.3.2 *Class DW*—Pipe, double-welded with no addition of filler metal.

1.4 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.5 Table 1 lists the dimensions of welded stainless steel pipe as shown in ANSI B36.19. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.6 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:* [2]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

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

E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys

E 527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *ANSI Standards:*[3]

B1.20.1 Pipe Threads, General Purpose

B31.3 Chemical Plant and Refinery Piping Code

B36.10 Welded and Seamless Wrought Steel Pipe

B36.19 Stainless Steel Pipe

2.3 *ASME Boiler and Pressure Vessel Code:*

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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 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.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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

TABLE 1 Dimensions of Welded and Seamless Stainless Steel Pipe[A]

NOTE 1—Table 1 is based on Table number 1 of the American National Standard for Stainless Steel Pipe (ANSI B36.19-1965).
NOTE 2—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[B]		Schedule 10S[B]		Schedule 40S		Schedule 80S	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
⅛	0.405	10.29	. . .	. . .	0.049[C]	1.24	0.068	1.73	0.095	2.41
¼	0.540	13.72	. . .	. . .	0.065[C]	1.65	0.088	2.24	0.119	3.02
⅜	0.675	17.15	. . .	. . .	0.065[C]	1.65	0.091	2.31	0.126	3.20
½	0.840	21.34	0.065[C]	1.65	0.083[C]	2.11	0.109	2.77	0.147	3.73
¾	1.050	26.67	0.065[C]	1.65	0.083[C]	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065[C]	1.65	0.109[C]	2.77	0.133	3.38	0.179	4.55
1¼	1.660	42.16	0.065[C]	1.65	0.109[C]	2.77	0.140	3.56	0.191	4.85
1½	1.900	48.26	0.065[C]	1.65	0.109[C]	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065[C]	1.65	0.109[C]	2.77	0.154	3.91	0.218	5.54
2½	2.875	73.03	0.083	2.11	0.120[C]	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120[C]	3.05	0.216	5.49	0.300	7.62
3½	4.000	101.60	0.083	2.11	0.120[C]	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120[C]	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109[C]	2.77	0.134[C]	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134[C]	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109[C]	2.77	0.148[C]	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134[C]	3.40	0.165[C]	4.19	0.365	9.27	0.500[C]	12.70[C]
12	12.750	323.85	0.156[C]	3.96	0.180[C]	4.57	0.375[C]	9.52[C]	0.500[C]	12.70[C]
14	14.000	355.60	0.156[C]	3.96	0.188	4.78	. . .	. . .	. . .	. . .
16	16.000	406.40	0.165[C]	4.19	0.188	4.78	. . .	. . .	. . .	. . .
18	18.000	457.20	0.165[C]	4.19	0.188	4.78	. . .	. . .	. . .	. . .
20	20.000	508.00	0.188[C]	4.78	0.218[C]	5.54	. . .	. . .	. . .	. . .
22	22.000	558.80	0.188[C]	4.78	0.218[C]	5.54	. . .	. . .	. . .	. . .
24	24.000	609.60	0.218[C]	5.54	0.250	6.35	. . .	. . .	. . .	. . .
30	30.000	762.00	0.250	6.35	0.312	7.92	. . .	. . .	. . .	. . .

[A]For pipe sizes not listed, the dimensions and tolerances shall be by agreement between the purchaser and producer.
[B]Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).
[C]These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10-1979).

Section VIII Division 1, Pressure Vessels[4]

2.4 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[5]

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing[6]

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, centimetres, or number of lengths),

3.1.2 Name of material (austenitic steel pipe),

3.1.3 Class (1.3). If not specified by the purchaser, the producer shall have the option to furnish either single-welded (SW) or double-welded (DW) pipe,

3.1.4 Grade (Table 2),

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

3.1.6 Length (specific or random), (Section 9),

3.1.7 End finish (section on Ends of Specification A 999/A 999M),

3.1.8 Optional requirements (hydrostatic or nondestructive electric test, Section 13,) (Supplementary Requirements S1 to S6),

3.1.9 Test report required (Section on Certification of Specification A 999/A 999M),

3.1.10 Specification number, and

3.1.11 Special requirements or exceptions to the specification.

4. Materials and Manufacture

4.1 *Manufacture*:

4.1.1 The pipe shall be made by a machine-welding or an automatic-welding process, welding from one or both sides and producing full penetration welds with no addition of filler metal in the welding operation.

4.1.2 Weld repairs, with the addition of compatible filler metal, may be made to the weld joint in accordance with the requirements of the section on Repair by Welding of Specification A 999/A 999M.

4.1.3 The pipe shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

4.2 *Heat Treatment*:

4.2.1 Except as provided in 4.2.6 and 4.2.7, all pipe shall be furnished in the heat-treated condition, except pipe sizes over NPS 6 may be furnished in the unheat-treated condition when specified in the order. When the pipe is furnished without final heat treatment, each pipe shall be marked HT-O and when a material test report for such pipe is furnished to the purchaser, the report shall indicate that the pipe has not been heat-treated.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[5] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

[6] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

TABLE 2 Chemical Requirements

Grade	UNS Designation[A]	Composition, %														
		Carbon, max[B]	Manganese, max[B]	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Titanium	Columbium	Tantalum, max	Nitrogen[C]	Vanadium	Copper	Cerium	Cobalt
TP304	S30400	0.08	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP304L	S30403	0.030[D]	2.00	0.045	0.030	1.00 max	8.0–12.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP304N	S30451	0.08	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .	. . .
TP304LN	S30453	0.030	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .	. . .
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00 max	12.0–16.0	22.0–24.0	. . .	. . .	10 × C min, 1.10 max	. . .	. . .	. . .	. . .	. . .	. . .
TP309S	S30908	0.08	2.00	0.045	0.030	1.00 max	12.0–15.0	22.0–24.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	. . .	. . .	10 × C min, 1.10 max	. . .	. . .	. . .	. . .	. . .	. . .
TP310S	S31008	0.08	2.00	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP316	S31600	0.08	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP316L	S31603	0.030[D]	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP316N	S31651	0.08	2.00	0.045	0.030	1.00 max	10.0–15.0	16.0–18.0	2.00–3.00				0.10–0.16	. . .	. . .	. . .	. . .
TP316LN	S31653	0.030[D]	2.00	0.045	0.030	1.00 max	10.0–13.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .	. . .
TP317	S31700	0.08	2.00	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP317L	S31703	0.030	2.00	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S31727	0.030	1.00	0.030	0.030	1.00 max	14.5–16.5	17.5–19.0	3.8–4.5	. . .	. . .	. . .	0.15–0.21	. . .	2.8–4.0	. . .	. . .
. . .	S32053	0.030	1.00	0.030	0.010	1.00 max	24.0–26.0	22.0–24.0	5.0–6.0	. . .	. . .	. . .	0.17–0.22	. . .	. . .	. . .	. . .
TP321	S32100	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	. . .	[E]	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	. . .	[F]	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP347	S34700	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	. . .	. . .	[G]	. . .	. . .	. . .	. . .	. . .	. . .
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	. . .	. . .	[H]	. . .	. . .	. . .	. . .	. . .	. . .
TP348	S34800	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	. . .	. . .	[G]	0.10	. . .	. . .	. . .	. . .	0.20 max
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	. . .	. . .	[H]	0.10	. . .	. . .	. . .	. . .	0.20 max
TPXM-10	S21900	0.08	8.0–10.0	0.045	0.030	1.00 max	5.5–7.5	19.0–21.5	. . .	. . .	. . .	. . .	0.15–0.40	. . .	. . .	. . .	. . .
TPXM-11	S21903	0.04	8.0–10.0	0.045	0.030	1.00 max	5.5–7.5	19.0–21.5	. . .	. . .	. . .	. . .	0.15–0.40	. . .	. . .	. . .	. . .
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.5–18.5	17.0–19.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TPXM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00 max	11.5–13.5	20.5–23.5	1.50–3.00	. . .	0.10–0.30	. . .	0.20–0.40	0.10–0.30	. . .	. . .	. . .
TPXM-29	S24000	0.08	11.5–14.5	0.060	0.030	1.00 max	2.3–3.7	17.0–19.0	. . .	. . .	. . .	. . .	0.20–0.40	. . .	. . .	. . .	. . .
. . .	S31254	0.020	1.00	0.030	0.010	0.80 max	17.5–18.5	19.5–20.5	6.0–6.5	. . .	. . .	. . .	0.18–0.22	. . .	0.50–1.00	. . .	. . .
. . .	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	. . .	. . .	. . .	. . .	0.14–0.20	. . .	. . .	0.03–0.08	. . .
. . .	N08367	0.030	2.00	0.040	0.030	1.00 max	23.5–25.5	20.0–22.0	6.0–7.0	. . .	. . .	. . .	0.18–0.25	. . .	0.75 max	. . .	. . .

[A] New designation established in accordance with ASTM E 527 and SAE J1086 Practice for Numbering Metals and Alloys (UNS).

[B] Maximum, unless otherwise indicated.

[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

[D] For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.044 in. [1 mm] in minimum wall thickness).

[E] The titanium content shall be not less than five times the carbon content and not more than 0.70 %.

[F] The titanium content shall be not less than four times the carbon content and not more than 0.70 %.

[G] The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.0 %.

[H] The columbium plus tantalum content shall be not less than eight times the carbon content and not more than 1.10 %.

The heat-treatment procedure, except for H grades, N08367, and S31254, shall consist of heating the pipe to a minimum temperature of 1900 °F [1040 °C] and quenching in water or rapidly cooling by other means.

4.2.2 All H grades shall be furnished in the solution-treated condition. If cold working is involved in processing, the minimum solution treating temperature for Grades TP321H, TP347H, and TP348H shall be 2000 °F [1100 °C] and for Grades TP304H and TP316H, 1900 °F [1040 °C]. If the H Grade is hot rolled, the minimum solution treating temperatures for Grades TP321H, TP347H, and TP348H shall be 1925 °F [1050 °C], and for Grades TP304H and TP316H, 1900 °F [1040 °C].

4.2.3 The heat-treatment procedure for S31254 shall consist of heating the pipe to a minimum temperature of 2100 °F [1150 °C] and quenching in water or rapidly cooling by other means.

4.2.4 S31727 and S32053 shall be heat treated 1975 to 2155 °F [1080 to 1180 °C] followed by quenching in water or rapidly cooling by other means.

4.2.5 UNS N08367 should be solution annealed from 2025 °F [1107 °C] minimum followed by rapid quenching.

4.2.6 Except for H Grades and S31254, pipe sizes over NPS 6 may be furnished in the unheat-treated condition when specified in the order.

4.2.7 H Grades and S31254 in pipe sizes NPS 6 may be furnished in the unheat-treated condition when specified in the order, provided the heat treatment of 4.2.2 or 4.2.3, as applicable, is applied by the purchaser.

4.2.8 When the pipe is furnished without final heat treatment, each pipe shall be marked HT-O and when a material test report for such pipe is furnished to the purchaser, the report shall indicate that the pipe has not been heat-treated.

5. Chemical Composition

5.1 The steel shall conform to the chemical composition in Table 2.

5.2 When specified on the purchase order, a product analysis shall be supplied from one tube or coil of steel per heat. The product analysis tolerance of Specification A 480/A 480M shall apply.

6. Product Analysis

6.1 At the request of the purchaser, an analysis of one length of flat-rolled stock from each heat, or one pipe from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel.

NPS Number	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5 inclusive	200 or fraction thereof
6 and over	100 or fraction thereof

6.2 The results of these analyses shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 5.

6.3 If the analysis of one of the tests specified in 6.1 does not conform to the requirements specified in Section 5, an analysis of each length of flat-rolled stock from each heat or pipe from the same heat or lot may be made, and all pipe conforming to the requirements shall be accepted.

6.4 For referee purposes, Test Methods, Practices, and Terminology A 751 shall be used.

7. Tensile Requirements

7.1 The tensile properties of the material shall conform to the requirements prescribed in Table 3.

8. Permissible Variations in Dimensions

8.1 Permissible variations in dimensions shall not exceed the following at any point in each length of pipe.

8.1.1 *Specified Diameter*—The outside diameter shall be based on circumferential measurement and shall not exceed the tolerances stated as follows:

8.1.1.1 For sizes up to and including NPS 1¼ , ±0.010 in. [±0.25 mm],

8.1.1.2 For sizes NPS 1½ up to and including NPS 6, ±0.020 in. [±0.5 mm],

8.1.1.3 For sizes NPS 8 up to and including NPS 18, ±0.030 in. [±0.75 mm],

8.1.1.4 For sizes NPS 20 up to and including NPS 24, ±0.040 in. [±1 mm], and

8.1.1.5 For sizes NPS 30, ±0.050 in. [±1.25 mm].

8.1.1.6 Outside diameter tolerances closer than shown above may be obtained by agreement between the pipe manufacturer and purchaser.

TABLE 3 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
TP304L	S30403	70 [485]	25 [170]
TP316L	S31603	70 [485]	25 [170]
TP304	S30400	75 [515]	30 [205]
TP304H	S30409	75 [515]	30 [205]
TP309Cb	S30940	75 [515]	30 [205]
TP309S	S30908	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP316	S31600	75 [515]	30 [205]
TP316H	S31609	75 [515]	30 [205]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
. . .	S31727	80 [550]	36 [245]
. . .	S32053	93 [640]	43 [295]
TP321	S32100	75 [515]	30 [205]
TP321H	S32109	75 [515]	30 [205]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21903	90 [620]	50 [345]
TPXM-15	S38100	75 [515]	30 [205]
TPXM-29	S24000	100 [690]	55 [380]
TPXM-19	S20910	100 [690]	55 [380]
TP304N	S30451	80 [550]	35 [240]
TP316N	S31651	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
TP316LN	S31653	75 [515]	30 [205]
. . .	S31254	94 [650]	44 [300]
. . .	S30815	87 [600]	45 [310]
. . .	N08367		
	$t \leq 0.187$	100 [690]	45 [310]
	$t > 0.187$	95 [655]	45 [310]

8.1.2 *Out-of-Roundness*—The difference between the major and the minor outside diameter shall not be more than 1.5 % of the specified outside diameter.

8.1.3 *Alignment (Camber)*—Using a 10-ft [3.0-m] straight-edge placed so that both ends are in contact with the pipe, the camber shall not be more than 3⁄16 in. [4.8 mm].

8.1.4 *Thickness*—The wall thickness at any point in the pipe excluding the weld, shall not be more than 12 % under or over the nominal thickness for wall thickness less than 0.188 in. [4.8 mm] and not more than 0.030 in. [0.8 mm] under or over the nominal thickness for wall thickness 0.188 in. [4.8 mm] and greater. Weld reinforcement not to exceed 20 % of the wall thickness is permitted on each of the inside and outside surfaces of the pipe.

9. Lengths

9.1 Pipe lengths shall be in accordance with the following regular practice:

9.1.1 Unless otherwise agreed upon, all sizes up to and including NPS 8 are available in a length up to 24 ft (Note 2) with the permissible range of 15 to 24 ft (Note 2). Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

NOTE 2—The 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.

9.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and not more than ¼ in. [6 mm] over that specified.

10. Workmanship, Finish, and Appearance

10.1 The finished pipes shall be free of injurious imperfections and shall have a workmanlike finish. Minor imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted in Section 8.

11. Examination of Double-Welded Pipe

11.1 Both ends of each double-welded (Class DW) pipe shall be visually examined to determine that complete fusion was attained between the two welds. In lieu of examining the ends of the pipe, this examination may be performed on cropped ends removed from both ends of each double welded pipe.

12. Mechanical Tests Required

12.1 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes. Pipe size greater than NPS 6 shall be tested using the transverse tension test with the weld centered in the gage length of the test specimen. Test specimens shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as prolongation of the pipe longitudinal weld seam.

NOTE 3—The term lot, for mechanical tests, applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment: (*1*) in a continuous heat-treatment furnace, or (*2*) in a batch-type heat-treatment furnace, equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] range, the larger of: (*a*) each 200 ft [60 m] or fraction thereof or (*b*) that pipe heat treated in the same batch furnace charge.

12.2 *Flattening Test*—For material heat treated in a batch-type furnace, flattening tests shall be made on 5 % of the pipe from each heat-treated lot. For material heat treated by the continuous process, this test shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than two lengths of pipe.

12.2.1 For pipe where the diameter equals or exceeds NPS 10, a transverse-guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A 370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5 % of the lot shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

13. Hydrostatic or Nondestructive Electric Test

13.1 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.

13.2 The hydrostatic test shall be in accordance with Specification A 999/A 999M.

13.3 *Nondestructive Examination*—Each pipe shall be examined with a nondestructive test in accordance with Practice E 213, or E 426. Unless specifically called out by the purchaser, the selection of the nondestructive electric test will be at the option of the manufacturer. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

13.3.1 The following information is for the benefit of the user of this specification:

13.3.1.1 The reference standards defined in 13.9.1-13.9.4 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

13.3.1.2 The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep, defects.

13.3.1.3 The eddy-current testing (ET) referenced in this specification, (Practice E 426), has the capability of detecting significant discontinuities, especially the short abrupt type.

13.3.1.4 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

13.4 *Time of Examination*:

13.4.1 Nondestructive testing for specification acceptance shall be performed after all mechanical processing, heat treatments, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

13.5 *Surface Condition*:

13.5.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

13.5.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

13.6 *Extent of Examination*:

13.6.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except as in 13.5.2.

13.6.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

13.7 *Operator Qualifications*:

13.7.1 The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent recognized and documented standard.

13.8 *Test Conditions*:

13.8.1 For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide good signal-to-noise ratio.

13.8.2 The maximum eddy-current coil frequency used shall be as follows:

On specified walls up to 0.050 in.—100 KHz max

On specified walls up to 0.150 in.—50 KHz max

On specified walls above 0.150 in.—10 KHz max

13.8.3 *Ultrasonic*—For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.00 MHz and the maximum nominal transducer size shall be 1.5 in.

(1) If the equipment contains a reject notice filter setting, this shall remain off during calibration and testing unless linearity can be demonstrated at that setting.

13.9 *Reference Standards*:

13.9.1 Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS, or outside diameter and schedule or wall thickness), surface finish and heat treatment condition as the pipe to be examined.

13.9.2 *For Ultrasonic Testing*, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of each notch shall not exceed 12½ % of the specified nominal wall thickness of the pipe or 0.004 in., whichever is greater. The width of the notch shall not exceed twice the depth. Notches shall be placed on both the OD and ID surfaces.

13.9.3 *For Eddy-Current Testing*, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

(1) Drilled Hole—The reference standard shall contain three or more holes, equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. One hole shall be drilled in the weld, if visible. Alternately, the producer of welded pipe may choose to drill one hole in the weld and run the calibration standard through the test coils three times with the weld turned at 120° on each pass. The hole diameter shall vary with NPS as follows:

NPS Designator	Hole Diameter
½	0.039 in. [1 mm]
above ½ to 1¼	0.055 in. [1.4 mm]
above 1¼ to 2	0.071 in. [1.8 mm]
above 2 to 5	0.087 in. [2.2 mm]
above 5	0.106 in. [2.7 mm]

(2) Transverse Tangential Notch—Using a round tool or file with a ¼ in. [6.4 mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding 12½ % of the specified nominal wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

(3) Longitudinal Notch—A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12½ % of the specified wall thickness of the pipe or 0.004 in., whichever is greater. The length of the notch shall be compatible with the testing method.

13.9.4 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

13.10 *Standardization Procedure*:

13.10.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness), Grade and heat treatment condition, and at intervals not exceeding 4 h. More frequent standardization may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

13.10.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss, process shutdown or when a problem is suspected.

13.10.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the pipe to be tested.

13.10.4 The signal-to-noise ratio for the reference standard shall be 2½ to 1 or greater. Extraneous signals caused by identifiable causes such as dings, scratches, dents, straightener marks, etc., shall not be considered noise. The rejection amplitude shall be adjusted to be at least 50 % of full scale of the readout display.

13.10.5 If upon any standardization, the rejection amplitude has decreased by 29 % (3 dB) of peak height from the last standardization, the pipe since the last calibration shall be rejected. The test system settings may be changed, or the transducer(s), coil(s) or sensor(s) adjusted, and the unit restandardized, but all pipe tested since the last acceptable standardization must be retested for acceptance.

13.11 *Evaluation of Imperfections*:

13.11.1 Pipes producing a signal equal to or greater than the lowest signal produced by the reference standard(s) shall be identified and separated from the acceptable pipes. The area producing the signal may be reexamined.

13.11.2 Such pipes shall be rejected if the test signal was produced by imperfections that cannot be identified or was produced by cracks or crack-like imperfections. These pipes may be repaired per Sections 4 and 10. To be accepted, a repaired pipe must pass the same non-destructive test by which it was rejected, and it must meet the minimum wall thickness requirements of this specification.

13.11.3 If the test signals were produced by visual imperfections such as:

(1) Scratches,
(2) Surface roughness,
(3) Dings,
(4) Straightener marks,
(5) Cutting chips,
(6) Steel die stamps,
(7) Stop marks, or
(8) Pipe reducer ripple.

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).

13.11.4 Rejected pipe may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed. To be accepted, retested pipe shall meet the test requirement.

13.11.5 If the imperfection is explored to the extent that it can be identified as non-rejectable, the pipe may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness.

14. Product Marking

14.1 In addition to that specified in Specification A 999/A 999M, the marking shall include the manufacturer's private identifying mark and identified as either single welded (SW) or double welded (DW) as applicable. For Grades TP304H, TP316H, TP321H, TP347H, and TP348H, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weights.

14.2 When heat treatment of the pipe is not performed, the pipe shall be marked HT-O.

14.3 When a hydrostatic test of the pipe is not performed, the pipe shall be marked NH.

15. General Requirements

15.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipes NPS 5 and larger in nominal size, there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5, there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 5 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This applies only to pipe NPS 8 and larger in nominal size.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be tested, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound welds and reasonably uniform material free of injurious laminations, cracks, and similar objectionable imperfections. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable imperfections, the length shall be rejected subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Radiographic Examination

S5.1 Weld soundness shall be determined through radiographic examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S6. Corrosion Requirements

S6.1 *Boiling Nitric Acid Test*—Except for Grade TP 321, coupons representing finished pipe made of nonmolybdenum-bearing material (0.50 % and less molybdenum) shall meet the requirements of Practice C of Practices A 262. The condition of the test specimens and the corrosion rates are as follows: Types 304L, 304LN, 347, and 348 shall be tested in the sensitized condition (heated for 1 h at 1240 °F [670 °C]) and the rate of penetration when the solution is tested in accordance with Practice C shall not exceed 0.0020 in. [0.05 mm] per month. All other nonmolybdenum-bearing types, except for Grade TP 321, shown in Table 2, shall be tested in the annealed and unsensitized condition and the rate of penetration shall not exceed 0.0015 in. [0.038 mm] per month.

S6.2 *Acidified Copper Sulfate Test*—Coupons representing finished pipe made of molybdenum-bearing material (over 0.50 % molybdenum) and Type 321 shall meet the requirements of Practice E of Practices A 262. The condition of the test specimen is as follows: Types 316L, 316LN, 317L, and 321 shall be tested in the sensitized condition (heated for 1 h at 1240 °F [670 °C]). All molybdenum-bearing types shown in Table 2 shall be tested in the annealed and unsensitized condition. All specimens shall meet the requirements of the prescribed bend tests.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 813/A 813M – 01(2005), that may impact the use of this specification. (Approved September 1, 2007)

(*1*) Added S31727 and S32053 to Tables 2 and 3 and introduced their heat treatment requirements in new 4.2.4 and renumbered subsequent paragraphs.

Standard Specification for Welded Ferritic Stainless Steel Feedwater Heater Tubes[1]

This standard is issued under the fixed designation A 803/A 803M; 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 covers welded ferritic stainless steel feedwater heater tubes including those bent, if specified, into the form of U-tubes for application in tubular feedwater heaters.

1.2 The tubing sizes covered shall be ⅝ to 1 in. [15.9 to 25.4 mm] inclusive, in outside diameter, and average or minimum wall thicknesses of 0.028 in. [0.7 mm] and heavier.

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 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat Resisting Steel Plate, Sheet, and Strip[2]

A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels[2]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys[3]

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes[3]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A 941.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (length or number of pieces),

4.1.2 Material description,

4.1.3 Dimensions (outside diameter, wall thickness (minimum or average wall), and length),

4.1.4 Grade (chemical composition) (Table 1), and

4.1.5 U-bend requirements, if order specifies bending, U-bend schedules or drawings shall accompany the order.

4.2 *Optional Requirements*—Purchaser shall specify whether annealing of the U-bends is required or whether tubes are to be hydrotested or air-tested (see 10.5).

4.3 *Supplementary Requirements*—Purchaser shall specify on this purchase order if material is to be eddy-current tested in accordance with Supplementary Requirement S1 or S2, and if special test reports are required, under Supplementary Requirement S3, and,

4.4 Any special requirements.

5. General Requirements

5.1 Material furnished to this specification shall conform to the applicable requirements of the latest published edition of Specification A 1016/A 1016M unless otherwise provided herein.

6. Materials and Manufacture

6.1 The tube shall be made from flat-rolled steel by an automatic welding process with no addition of filler metal.

6.2 Surface contaminants may have detrimental effects on high temperature properties or corrosion resistance of tubing. Contamination by copper, lead, mercury, zinc, chlorides, or sulfur may be detrimental to stainless steels. The manufacturer shall employ techniques which minimize surface contamination by these elements.

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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.

Current edition approved Sept. 10, 2003. Published October 2003. Originally approved in 1982. Last previous edition approved in 2002 as A 803/A 803M – 02.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

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

TABLE 1 Chemical Requirements

Grade	UNS S 40900 TP409	UNS S 43035 TP439	UNS S 44627 TP XM-27	UNS S 44626 TP XM-33	UNS S 44635 25-4-4	UNS S 44660 26-3-3	UNS S 44700 29-4	UNS S 44800 29-4-2	UNS S 44400 18-2	UNS S 44735 29-4C
Element	Composition, %									
C, max	0.08	0.07	0.01[A]	0.06	0.025	0.030	0.010	0.010	0.025	0.030
Mn, max	1.00	1.00	0.40	0.75	1.00	1.00	0.30	0.30	1.00	1.00
P, max	0.045	0.040	0.02	0.040	0.040	0.040	0.025	0.025	0.040	0.040
S, max	0.030	0.030	0.02	0.020	0.030	0.030	0.020	0.020	0.030	0.030
Si, max	1.00	1.00	0.40	0.75	0.75	1.00	0.20	0.20	1.00	1.00
Ni	0.50 max	0.50 max	0.5[B] max	0.50 max	3.5–4.5	1.0–3.5	0.15 max	2.0–2.5	1.00 max	1.00 max
Cr	10.5–11.7	17.0–19.0	25.0–27.5	25.0–27.0	24.5–26.0	25.0–28.0	28.0–30.0	28.0–30.0	17.5–19.5	28.0–30.0
Mo	. . .	. . .	0.75–1.50	0.75–1.50	3.5–4.5	3.0–4.0	3.5–4.2	3.5–4.2	1.75–2.50	3.6–4.2
Al	. . .	0.15 max	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Cu	. . .	. . .	0.20 max	0.20 max	. . .	. . .	0.15 max	0.15 max	. . .	. . .
N	. . .	0.04 max	0.015 max	0.040 max	0.035	0.040 max	0.020 max[C]	0.020 max[C]	0.035 max	0.045 max
Ti	6 × C min; 0.75 max	0.20 + 4 (C + N) min; 1.10 max	. . .	7 × (C + N) but no less than 0.20 min; 1.00 max	(Ti + Cb) = 0.2 + 4 (C + N) min; 0.80 max	Ti + Cb = 6 × (C + N) but no less than 0.20 min; 1.00 max			(Ti + Cb) = 0.20 + 4 (C + N) min; 0.80 max	Ti + Cb = 6 × (C + N) but no less than 0.20 min; 1.00 max
Cb	. . .	. . .	0.05–0.20	. . .	. . .	. . .	. . .	. . .	. . .	. . .

[A] For small diameter or thin walls, or both, tubing, where many drawing passes are required, a carbon maximum of 0.015 % is necessary. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.040 in. [1 mm] in minimum wall thickness).

[B] Nickel + copper.

[C] Carbon + nitrogen = 0.025 max.

7. Cleaning Before Annealing

7.1 All lubricants or coatings used in the manufacture of straight-length tube or in the bending shall be removed from all surfaces prior to any annealing treatments. U-bends on which a lubricant had been applied to the inside surface during bending shall have the cleanness of their inside surface confirmed by blowing close-fitting acetone-soaked felt plugs through 10 % of the tubes of each bend radius. Dry, oil-free air or inert gas shall be used to blow the plugs through the tubes. If the plugs blown through any tube show more than a light gray discoloration, all tubes that have had a lubricant applied to the inside surface during bending shall be recleaned. After recleaning 10 % of the tubes of each bend radius whose inside surface had been subjected to bending, lubricants shall be retested.

8. Heat Treatment

8.1 All finished straight tubing or straight tubing ready for U-bending shall be furnished in the solution-annealed condition. The annealing procedure shall consist of heating the material to a temperature of 1200°F [650°C] or higher and cooling (as appropriate for the grade) to meet the requirements of this specification.

8.2 If heat treatment of U-bends is specified, it shall satisfy the annealing procedure described in 8.1 and shall be done as follows:

8.2.1 The heat treatment shall be applied to the U-bend area plus approximately 6 in. [150 mm] of each leg beyond the tangent point of the U-bend.

8.2.2 If the heat treatment specified in 8.2 is accomplished by resistance-heating methods wherein electrodes are clamped to the tubes, the clamped areas shall be visually examined for arc burns. Burn indications shall be cause for rejection unless they can be removed by local polishing without encroaching upon minimum wall thickness.

8.2.3 Temperature control shall be accomplished through the use of optical or emission pyrometers, or both. No temperature-indicating crayons, lacquers, or pellets shall be used.

8.2.4 The inside of the tube shall be purged with a protective or an inert gas atmosphere during heating and cooling to below 700°F [370°C] to prevent scaling of the inside surface. The atmosphere should be noncarburizing.

9. Chemical Composition

9.1 *Product Analysis*:

9.1.1 The steel shall conform to the chemical composition in Table 1.

9.1.2 When specified on the purchase order, a product analysis shall be supplied from one tube or coil of steel per heat. The product analysis tolerance of Specification A 480/A 480M shall apply.

9.1.3 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of this specification; otherwise all remaining material in the heat or lot (see Note 1) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes that do not meet the requirements of this specification shall be rejected.

NOTE 1—For product analyses and flange requirements, the term "lot" applies to 125 tube groupings, prior to cutting to length, of the same nominal size and wall thickness, produced from the same heat of steel and annealed in a continuous furnace.

10. Mechanical Requirements

10.1 *Tensile Properties*:

10.1.1 The material shall conform to the tensile properties shown in Table 2.

10.1.2 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 (Note 2).

10.1.3 Table 3 gives the computed minimum elongation values for each 1⁄32 in. [0.8 mm] decrease in wall thickness.

10.2 *Hardness*:

10.2.1 The tubes shall have a hardness number not to exceed those prescribed in Table 4. This hardness requirement is not to apply to the bend area of U-bend tubes which are not heat treated after bending.

10.2.2 Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (see Note 2).

NOTE 2—For tension, hardness, and corrosion test requirements, the term "lot" applies to all tubes prior to cutting to length, of the same nominal diameter and wall thickness, produced from the same heat of steel and annealed in a continuous furnace at the same temperature, time at heat, and furnace speed.

10.3 *Reverse Flattening Test*—One reverse flattening test shall be made on a specimen from each 1500 ft [460 m] of finished tubing.

10.4 *Flange Test*—Flange tests shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (see Note 1).

10.5 *Pressure Test*—Each straight tube, or each U-tube after completion of the bending and post-bending heat treatment, shall be pressure-tested in accordance with one of the following paragraphs as specified by the purchaser:

10.5.1 *Hydrostatic Test*—Each tube shall be given an internal hydrostatic test in accordance with Specification A 1016/A 1016M.

10.5.2 *Air Underwater Test*—Each tube shall be air underwater tested in accordance with Specification A 1016/A 1016M.

TABLE 2 Tensile Requirements

Grade	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation[A] in 2 in. or 50 mm, min, %
TP 409	55 [380]	30 [205]	20
TP 439	60 [415]	30 [205]	20
TP XM-27	65 [450]	40 [275]	20
TP XM-33	68 [470]	45 [310]	20
25-4-4	90 [620]	75 [515]	20
26-3-3	85 [585]	65 [450]	20
29-4	80 [550]	60 [415]	20
29-4-2	80 [550]	60 [415]	20
18-2	60 [415]	35 [240]	20
29-4C	75 [515]	60 [415]	18

[A] For longitudinal strip tests, a deduction of 0.90 % for 29-4C and 1 % for all other grades shall be made from the basic minimum elongation for each 1⁄32 in. [0.8 mm] decrease in wall thickness below 5⁄16 in. [8 mm]. Table 3 gives the computed minimum values.

TABLE 3 Minimum Elongation Values[A]

Wall Thickness[B] in.	mm	Elongation in 2 in. or 50 mm, min, % 29-4C	All Other
5⁄16 (0.312)	8	18	20
9⁄32 (0.281)	7.2	17	19
1⁄4 (0.250)	6.4	16	18
7⁄32 (0.219)	5.6	15	17
3⁄16 (0.188)	4.8	14	16
5⁄32 (0.156)	4	13	15
1⁄8 (0.125)	3.2	13	14
3⁄32 (0.094)	2.4	12	13
1⁄16 (0.062)	1.6	11	12
0.062 to 0.035, excl	1.6 to 0.9	10	12
0.035 to 0.022, excl	0.9 to 0.6	10	11
0.022 to 0.015, excl	0.6 to 0.4	10	11

[A] Calculation elongation shall be rounded to the nearest whole number.
[B] Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

Grade	Equation
29-4C	$E = 28.8t + 9.00$
	$[E = 1.13t + 9.00]$
All other	$E = 32t + 10.00$
	$[E = 1.25t + 10.00]$

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

TABLE 4 Hardness Requirements

Grade	Brinell Hardness, max	Rockwell Hardness, B Scale, max
TP 409	207	95
TP 439	207	95
P XM-27	241	100
TP XM-33	241	100
25-4-4	270	27[A]
26-3-3	265	25[A]
29-4	241	100
29-4-2	241	100
18-2	217	95
29-4C	241	100

[A] Rockwell Hardness, C scale.

11. Corrosion Resisting Properties

11.1 One full section sample 1 in. [25 mm] long from the center of a sample tube of the smallest radius bend that is heat treated shall be tested in the heat treated condition in accordance with the appropriate practice in Practices A 763 for the specified grade, or as agreed upon for TP409.

11.2 One full-section sample 1 in. [25 mm] long from each lot (Note 2) of straight tubes shall be tested in the finished condition in accordance with the appropriate practice in Practices A 763 for the specified grade, or as agreed upon for TP409.

11.3 The appearance of any fissures or cracks in the test specimen, when evaluated in accordance with the Evaluation Sections of Practices A 763 indicating the presence of intergranular attack, shall be cause for rejection of that lot.

12. Permissible Variations in Dimensions (Fig. 1)

12.1 Permissible variations from the specified outside diameter shall be in accordance with Specification A 1016/

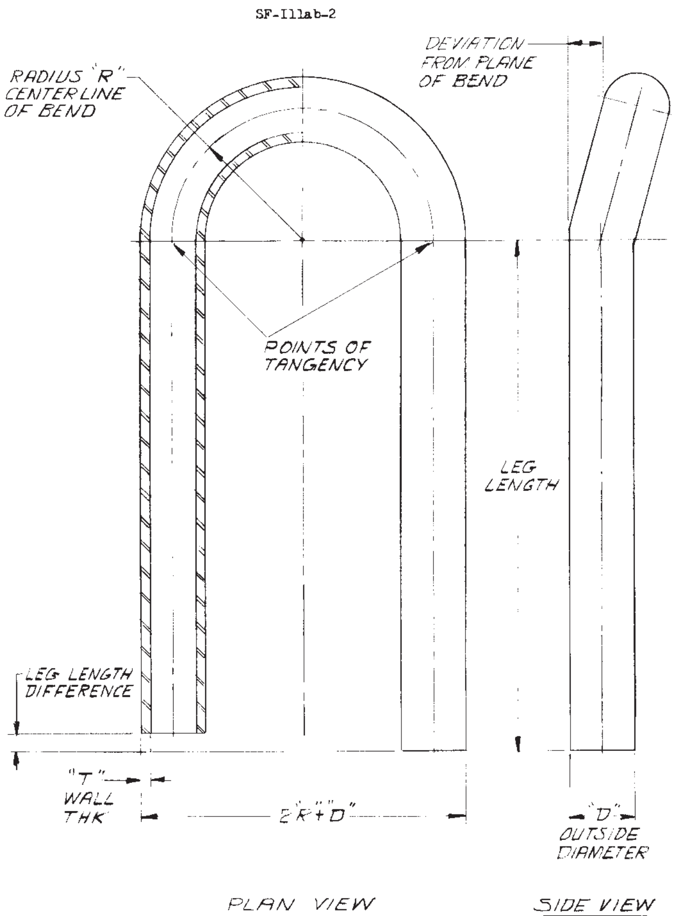

FIG. 1 Plane Bend for U-Tube

A 1016M. Those tolerances do not apply to the bent portion of the U-tubes. At the bent portion of a U-tube for $R = 2 \times D$ or greater, neither the major nor minor diameter of the tube shall deviate from the nominal diameter prior to bending by more than 10 %. If less than $2 \times D$ is specified, tolerances could be greater.

12.2 *Permissible Variations from the Specified Wall Thickness*:

12.2.1 Permissible variations from the specified minimum wall thickness shall not exceed +20 − 0 %.

12.2.2 Permissible variations from the specified average wall thickness are ±10 % of the nominal wall thickness.

12.2.3 The wall thickness of the tube in the U-bent section shall not be less than value determined by the equation:

$$t_f = \frac{4RT}{4R + D}$$

where:

t_f = wall thickness after bending, in. [mm],
T = specified minimum tube wall thickness, in. [mm],
R = centerline bend radius, in. [mm], and
D = nominal outside tube diameter, in. [mm].

12.3 *Permissible Variations from the Specified Length*:

12.3.1 *Straight Lengths*—The maximum permissible variations for lengths 24 ft [7.3 m] and shorter shall be +⅛ in. [+3 mm], −0; for lengths longer than 24 ft [7.3 m], an additional over tolerance of +⅛ in. [+3 mm] for each 10 ft [3 m], or fraction thereof, shall be permitted up to a maximum of +½ in. [+13 mm].

12.3.2 *U-Bends*—In the case of U-tubes, the length of the tube legs, as measured from the point of tangency of the bend and the tube leg to the end of the tube leg, shall not be less than specified, but may exceed the specified values by the amount given in Table 5. The difference in lengths of the tube legs shall not be greater than ⅛ in. [3 mm] unless otherwise specified.

12.4 The end of any tube may depart from square by not more than the amount given in Table 6.

12.5 The leg spacing measured between the points of tangency of the bend to the legs shall not vary from the value (2*R*-specified tube outside diameter) by more than 1⁄16 in. [1.5 mm] where *R* is the center-line bend radius.

12.6 The bent portion of the U-tube shall be substantially uniform in curvature, and not to exceed ± 1⁄16 in. [±1.5 mm] of the nominal center-line radius.

12.7 Permissible deviation from the plane of bend (see Fig. 1) shall not exceed 1⁄16 in. [1.5 mm] as measured from the points of tangency.

13. Workmanship, Finish, and Appearance

13.1 Tubing purchased to this specification is intended for use in heat exchangers and will be inserted through close-fitting holes in baffles or support plates, or both, spaced along the tube length. The tube ends will also be inserted into very close-fitting holes in a tubesheet and expanded and may be welded therein. The tubes shall be able to stand expanding and bending without showing cracks and flaws, and shall be finished reasonably straight and suitable for the intended purpose. Surface defects that violate minimum wall requirements shall be cause for rejection.

13.2 The residual chloride salt contamination of the inside and outside surface of the tubing at the time of packing for shipment from the mill shall not exceed a concentration of 1 mg/ft^3 [10.7 mg/m^2] of tube surface. One tube in each 500 pieces shall be checked immediately prior to packing for shipment for chloride salt contamination by a procedure agreed to between the manufacturer and purchaser.

14. Surface Condition

14.1 The straight tubes, after final annealing, shall be pickled using a solution of nitric and hydrofluoric acids followed by flushing and rinsing in water. If bright-annealing is performed, this requirement does not apply.

14.1.1 All tubes shall be free of excessive mill scale, suitable for inspection. A slight amount of oxidation will not be considered as scale. Any special finish requirements shall be subject to agreement between the manufacturer and the purchaser.

TABLE 5 Tube Leg Length Tolerance

Leg Length, ft [m]	Plus Tolerance, in. [mm]
Up to 20 [6], incl	⅛ [3.2]
Over 20 to 30 [6 to 9], incl	5⁄32 [4.0]
Over 30 to 40 [9 to 12], incl	3⁄16 [4.8]

TABLE 6 Squareness of Ends Tolerance

Tube OD, in. [mm]	Tolerance, in. [mm]
Up to ⅝ [15.9], incl	0.010 [0.25]
Over ⅝ to 1 in. [15.9 to 25.4], incl	0.016 [0.41]

14.2 A light oxide scale on the outside surface of U-bend area shall be permitted for tubes that have been electric-resistance heat treated after bending.

15. Nondestructive Test (Electric Test)

15.1 Each straight tube shall be tested after the finish heat treatment by passing it through a nondestructive tester capable of detecting defects on the entire cross section of the tube in accordance with Specification A 1016/A 1016M.

16. Inspection

16.1 The inspector representing the purchaser shall have entry, at all times, to those areas where inspection and testing is being performed on the purchaser's ordered material. The manufacturer shall afford the inspector all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. All required tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

17. Rejection

17.1 Each length of tubing received from the manufacturer may be inspected by the purchaser, and, if it does not meet the requirements of the specification based on the inspection and test method outlined in the specification, the tubing may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

17.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective, shall be set aside, and the manufacturer shall be notified. Disposition of such material shall be a matter for agreement between the manufacturer and the purchaser.

18. Certification

18.1 A test report, signed by an authorized employee or representative of the manufacturer, shall be furnished to the purchaser to indicate the specification and grade, the results of the heat analysis, hardness, and tensile properties. Product analysis will be reported only when requested on the purchase order as provided in 9.1.1.

19. Product Marking

19.1 All tubes shall be marked with the heat number.

19.2 Containers and packages shall be marked or tagged to show the purchaser's order number, the manufacturer's order number, specification, grade, size and gage of tubing, number of pieces contained in the package, and item number (if appropriate).

20. Packaging

20.1 All tubing shall be packaged and blocked in such a manner as to prevent damage in ordinary handling and transportation. The boxes shall be constructed in such a manner that no nails, staples, screws, or similar fasteners are required to close and secure the box after the tubes have been placed in the box. The box shall be lined with plastic sheet or vapor barrier materials so as to prevent chloride contamination of the tube during handling, transportation, and storage.

20.2 The U-bent tubes shall be arranged in boxes so that the smaller radius bends may be removed without disturbing larger radius bends. Tubes for an item number shall be boxed together.

21. Keywords

21.1 feedwater heater tubes; ferritic stainless steel; seamless steel tube; stainless steel tube; steel tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid and purchase order or contract. These requirements shall not be considered, unless specified in the order, in which event the necessary tests shall be made by the manufacturer prior to the bending or shipment of the tubing.

S1. Nondestructive Eddy-Current Test

S1.1 Each tube in the finished condition, except for bending if that is required, shall be tested by passing it through an electric nondestructive tester capable of detecting defects on the entire cross section of the tube. Suitable instrumentation shall be used to clearly distinguish the artificial defects. The outside and inside surfaces of the tubes shall be free of loose scale, metallic particles, or other material that would tend to restrict signals or create electrical noise. The tubing shall be inspected by feeding it longitudinally through an inspection coil or coils with a diameter suitable for the diameter of tubing to be inspected. The instrument calibration shall be accomplished with a reference standard prepared from the appropriate length of selected tubing of the same size, grade, and physical condition as the material to be inspected. The standard shall be fed through the coil at the same speed that the inspection of the tubing is performed.

S1.2 The factors listed in S1.3 shall be selected or adjusted, or both, in accordance with the instrument manufacturer's instructions, for the particular instrument involved as required to achieve optimum instrument distinction between the reference defects and plain portions of the tube.

S1.3 The following as well as other factors involved shall not be used in such a manner that they detract from the overall ability of the instrument to detect defects: test frequency, direct-current saturation level, filter networks, phase-analysis circuits, coil diameter, and instrument gain.

S1.4 The reference standard shall consist of a defect-free sample of the same size, alloy, and condition (temper) as that being tested, and shall contain longitudinal and circumferential notches on the outside diameter establishing the rejection level of the tubing to be tested. Inside diameter notches, both longitudinal and transverse, shall also be a part of the reference standard. These inside notches may be larger than the outside notches, and are intended for use only to assure instrument phase settings capable of yielding optimum inside surface sensitivity.

S1.4.1 All notches shall be produced by EDM methods. The outside diameter notches shall be of the dimensions shown in Table S1.1. See also Fig. S1.1.

S1.5 All tubing shall meet this specification. The instrument calibration shall be verified at the start of testing, after any shut down of the test equipment, after any test equipment adjustment, or at least every ½ h of continuous production testing, or both. Tubes generating a signal above the outside-diameter calibration standard sensitivity level shall be rejected.

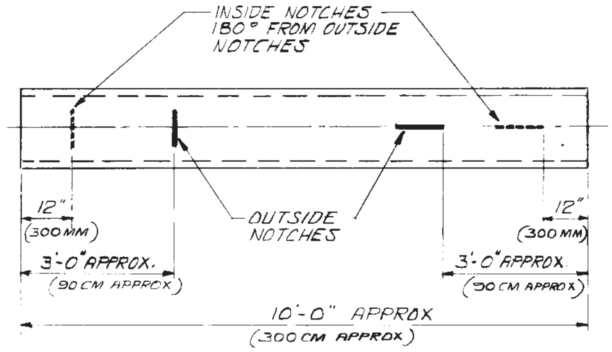

FIG. S1.1 Eddy-Current Test Standard

S1.6 Tubes may be reconditioned and retested provided reconditioning does not adversely effect the minimum wall thickness or other properties of the tube specification requirements. Upon agreement between purchaser and manufacturer, the referee method, employing ultrasonic testing, may be employed for retesting tubes rejected by the eddy-current test. The calibration standard for this test shall be identical to that required for the eddy-current test.

TABLE S1.1 Notch Depth[A]

OD, in. [mm]	Wall, in. [mm]	Depth, max in. [mm]	Length, max, in. [mm]	Width, max
⅝ to 1 [15.9 to 25.4] incl	0.028 [0.71] and heavier	0.005 [0.12] or 10.8 % of specified average wall (when average wall is ordered), or 11.8 % of specified minimum wall (when minimum wall is ordered), whichever is greater	0.375 [9.52]	wall thickness, but not greater than 0.062 in. [1.6 mm]

[A] The tolerance of notch depth shall be ±8 % or ±0.0005 in. [0.01 mm], whichever is greater. Refer to Fig. S1.1 for notch location orientation and length of calibration standard.

S2. Nondestructive Eddy-Current Testing (Select Commercial Grade)

S2.1 The manufacturer shall test the tubing using the procedure outlined in Supplementary Requirement S1, except for the notch standards, which shall be as indicated in Table S2.1.

S3. Report

S3.1 A report shall be furnished by the manufacturer to include a record of all tests performed to qualify material to this specification. This record shall include numbers of tests performed and qualitative or quantitative results as are applicable.

TABLE S2.1 Notch Depth for Select Commercial Grade

OD, in. [mm]	Wall, in. [mm]	Depth, max in. [mm]	Length, max, in. [mm]	Width, max
⅝ to 1 [15.9 to 25.4], incl	0.035 [0.9 mm] and heavier	0.005 [0.12] or 10.8 % of specified average wall (when average wall is ordered), or 11.8 % of specified minimum wall (when minimum wall is ordered), whichever is greater	0.375 [9.5]	3 times notch depth
⅝ to 1 [15.9 to 25.4], incl	less than 0.035 [0.9 mm]		0.375 [9.5]	wall thickness

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 803/A 803M – 02, which may impact the use of this specification (Approved September 10, 2003).

(1) Clarified ordering requirements to include purchaser's responsibility in Section 4.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 803/A 803M – 01, which may impact the use of this specification (Approved July 10, 2002).

(1) Specification A 450/A 450M has been changed to A 1016/ A 1016M throughout.

Designation: A 795/A 795M – 07

Standard Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Fire Protection Use[1]

This standard is issued under the fixed designation A 795/A 795M; 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 covers black and hot-dipped galvanized welded and seamless steel pipe in NPS 1/2 to NPS 10, inclusive [DN 15 to DN 250, inclusive] (Note 1), with wall thicknesses as given in Table 1 and Table 2. Pipe having other wall thicknesses may be furnished provided such pipe complies with all other requirements of this specification and the outside diameter is as given in Table 2. Pipe ordered under this specification is intended for use in fire protection systems. The pipe may be bent, but it is not intended for bending made at ambient temperature wherein the inside diameter of the bend is less than twelve times the outside diameter of the pipe being bent (Note 2).

NOTE 1—The dimensionless designators NPS (nominal pipe size) and DN (nominal diameter) have been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

NOTE 2—Successful bending of pipe is a function of equipment and technique as well as pipe properties.

1.2 This pipe is suitable for joining by the following methods:

1.2.1 *Light-Weight Fire Protection Pipe*—Rolled groove, welding, and fittings for plain end pipe. See Table 1 for dimensions.

1.2.2 *Standard-Weight Fire Protection Pipe*—Cut or rolled groove, threading, welding, and fittings for plain end pipe. See Table 2 for dimensions.

1.2.3 For pipe having dimensions other than those of Table 1 and Table 2, the joining method must be compatible with the pipe dimensions. A complete listing of standard light weight dimensions appears in ASME B36.10 and B36.19.

1.3 The following safety hazards caveat pertains only to the test method portion, Sections 8, 9, and 10, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

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.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 865 Specification for Threaded Couplings, Steel, Black or Zinc-Coated (Galvanized) Welded or Seamless, for Use in Steel Pipe Joints

B 6 Specification for Zinc

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

2.2 *ASME Standards:*

B1.20.1 Pipe Threads, General Purpose, Inch[3]

B36.10 Welded and Seamless Wrought Steel Pipe[3]

B36.19 Stainless Steel Pipe[3]

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[4]

2.4 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[4]

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved July 1, 2007. Published August 2007. Originally approved in 1982. Last previous edition approved in 2004 as A 795/A 795M–04.

[2] 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.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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

TABLE 1 Dimensions, Weights, and Test Pressure For Light-Weight Fire Protection Pipe—Schedule 10[A]

NPS Designator	DN Designator	Outside Diameter		Nominal Wall Thickness		Weight Plain End		Test Pressure: Furnace-Welded		Test Pressure: Seamless and Electric-Resistance-Welded	
		in.	mm	in.	mm	lb/ft	kg/m	psi	kPa	psi	kPa
¾	20	1.050	[26.7]	0.083	[2.11]	0.86	[1.28]	500	[3400]	700	[4800]
1	25	1.315	[33.4]	0.109	[2.77]	1.41	[2.09]	500	[3400]	700	[4800]
1¼	32	1.660	[42.2]	0.109	[2.77]	1.81	[2.69]	500	[3400]	1000	[6900]
1½	40	1.900	[48.3]	0.109	[2.77]	2.09	[3.11]	500	[3400]	1000	[6900]
2	50	2.375	[60.3]	0.109	[2.77]	2.64	[3.93]	500	[3400]	1000	[6900]
2½	65	2.875	[73.0]	0.120	[3.05]	3.53	[5.26]	500	[3400]	1000	[6900]
3	80	3.500	[88.9]	0.120	[3.05]	4.34	[6.46]	500	[3400]	1000	[6900]
3½	90	4.000	[101.6]	0.120	[3.05]	4.98	[7.41]	500	[3400]	1200	[8300]
4	100	4.500	[114.3]	0.120	[3.05]	5.62	[8.37]	500	[3400]	1200	[8300]
5	125	5.563	[141.3]	0.134	[3.40]	7.78	[11.58]	[B]	[B]	1200	[8300]
6	150	6.625	[168.3]	0.134	[3.40]	9.30	[13.85]	[B]	[B]	1000	[6900]
8	200	8.625	[219.1]	0.188[C]	[4.78]	16.96	[25.26]	[B]	[B]	800	[5500]
10	250	10.750	[273.1]	0.188[C]	[4.78]	21.23	[31.62]	[B]	[B]	700	[4800]

[A] Schedule 10 corresponds to Schedule 10S as listed in ANSI B36.19 for NPS ¾ through 6 [DN 20 through 150] only.
[B] Furnace-welded pipe is not made in sizes larger than NPS 4 [DN 100].
[C] Not Schedule 10.

TABLE 2 Dimensions, Weights, Test Pressures For Standard-Weight Fire Protection Pipe—Schedule 30 and Schedule 40

NPS Designator	DN Designator	Specified Outside Diameter		Nominal Wall Thickness[A]		Weight Plain End		Weight Threaded and Coupled[B]		Test Pressure: Furnace-Welded		Test Pressure: Seamless and Electric-Resistance-Welded	
		in.	mm	in.	mm	lb/ft	kg/m	lb/ft	kg/m	psi	kPa	psi	kPa
½	15	0.840	[21.3]	0.109	[2.77]	0.85	[1.27]	0.85	[1.27]	700	[4800]	700	[4800]
¾	20	1.050	[26.7]	0.113	[2.87]	1.13	[1.69]	1.13	[1.68]	700	[4800]	700	[4800]
1	25	1.315	[33.4]	0.133	[3.38]	1.68	[2.50]	1.68	[2.50]	700	[4800]	700	[4800]
1¼	32	1.660	[42.2]	0.140	[3.56]	2.27	[3.39]	2.28	[3.40]	1000	[6900]	1000	[6900]
1½	40	1.900	[48.3]	0.145	[3.68]	2.72	[4.05]	2.73	[4.07]	1000	[6900]	1000	[6900]
2	50	2.375	[60.3]	0.154	[3.91]	3.66	[5.45]	3.69	[5.50]	1000	[6900]	1000	[6900]
2½	65	2.875	[73.0]	0.203	[5.16]	5.80	[8.64]	5.83	[8.68]	1000	[6900]	1000	[6900]
3	80	3.500	[88.9]	0.216	[5.49]	7.58	[11.29]	7.62	[11.35]	1000	[6900]	1000	[6900]
3½	90	4.000	[101.6]	0.226	[5.74]	9.12	[13.58]	9.21	[13.71]	1200	[8300]	1200	[8300]
4	100	4.500	[114.3]	0.237	[6.02]	10.80	[16.09]	10.91	[16.25]	1200	[8300]	1200	[8300]
5	125	5.563	[141.3]	0.258	[6.55]	14.63	[21.79]	14.82	[22.07]	[C]	[C]	1200	[8300]
6	150	6.625	[168.3]	0.280	[7.11]	18.99	[28.29]	19.20	[28.60]	[C]	[C]	1200	[8300]
8	200	8.625	[219.1]	0.277[A]	[7.04]	24.72	[36.82]	25.57	[38.09]	[C]	[C]	1200	[8300]
10	250	10.750	[273.1]	0.307[A]	[7.80]	34.27	[51.05]	35.78	[53.29]	[C]	[C]	1000	[6900]

[A] NPS ½ through 6 [DN 15 through 150]—Schedule 40; NPS 8 and 10 [DN 200 and 250]—Schedule 30.
[B] Based on 20-ft [6.1-m] lengths.
[C] Furnace-welded pipe is not made in sizes larger than NPS 4 [DN 100].

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *defect*—an imperfection of sufficient size or magnitude to be cause for rejection.

3.1.2 *imperfection*—any discontinuity or irregularity found in the pipe.

4. Classification

4.1 Pipe may be furnished in the following types (Note 3):

4.1.1 *Type F*—Furnace-butt welded, continuous welded,

4.1.2 *Type E*—Electric-resistance-welded, or

4.1.3 *Type S*—Seamless.

NOTE 3—See Annex A1 for definitions of the types of pipe.

5. Ordering Information

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

5.1.1 Quantity (feet, metres, or number of lengths),

5.1.2 Name of material (steel pipe),

5.1.3 Type (seamless, electric-resistance-welded, or furnace-welded),

5.1.4 Grade (seamless and electric-resistance-welded only),

5.1.5 Size (NPS or DN designator and weight class; standard weight or light weight; or outside diameter) and wall thickness (Table 1 and Table 2),

5.1.6 Finish (black, galvanized, or other type of coating as specified by the purchaser),

5.1.7 Length (specific or random),

5.1.7.1 Grade for Type E and Type S,

5.1.8 End finish,

5.1.8.1 Plain end, square cut,

5.1.8.2 Plain end, beveled,

5.1.8.3 Cut groove (Note 4),

5.1.8.4 Rolled groove (Note 4),

5.1.8.5 Threads only,

5.1.8.6 Threaded and coupled, and

5.1.8.7 Couplings power tight.

NOTE 4—Type of groove specified by the purchaser.

5.1.9 ASTM designation.

6. Materials and Manufacture

6.1 The steel for both welded and seamless pipe shall be made by one or more of the following processes: open-hearth, electric-furnace, or basic-oxygen.

6.2 Welded pipe NPS 4 [DN 100] and under may be furnace-welded or electric-resistance welded. Welded pipe over NPS 4 [DN 100] shall be electric-resistance-welded.

6.3 The weld seam of electric-resistance-welded pipe in Grade B shall be heat treated after welding to a minimum of 1000 °F [540 °C] so that no untempered martensite remains, or otherwise processed in such a manner that no untempered martensite remains.

7. Chemical Composition

7.1 The steel shall conform to the requirements as to chemical composition specified in Table 3.

7.2 An analysis of two pipes from each lot of 500 lengths, or fraction thereof, may be made by the purchaser. The chemical composition thus determined shall conform to the requirements specified in Table 3.

7.3 Methods, practices, and definitions for chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

7.4 If the analysis of either pipe does not conform to the requirements specified in Table 3, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified in Table 3.

8. Hydrotest

8.1 Each length of pipe shall be subjected to a hydrostatic test by the manufacturer. The minimum test pressure shall be as prescribed in Table 1 and Table 2. This does not prohibit testing at a higher pressure at the manufacturer's option. The manufacturer may apply the hydrostatic test to pipe with plain ends, with threads only, or with threads and couplings. The hydrostatic test may be applied to single or multiple lengths.

8.2 The hydrostatic test shall be applied, without leakage through the pipe wall, to each length of pipe.

NOTE 5—The hydrostatic test pressures given herein are inspection test pressures. They are not intended as a basis for design and do not have any direct relationship to working pressures.

TABLE 3 Chemical Requirements

	Composition, max, %			
	C	Mn	P	S
Type E (electric-resistance-welded pipe) & Type S (seamless pipe)				
Open-hearth, electric-furnace or basic-oxygen:				
Grade A	0.25	0.95	0.035	0.035
Grade B	0.30	1.20	0.035	0.035
Type F (furnace-welded pipe)				
Open-hearth, electric-furnace, or basic oxygen			0.050	0.045

9. Nondestructive Electric Test

9.1 As an alternative to the hydrostatic test, and when accepted by the purchaser, test each pipe with a nondestructive electric test in accordance with Practice E 213 or Practice E 309. It is the intent of this test to reject pipe containing defects.

9.2 The following information is for the benefit of the user of this specification:

9.2.1 The ultrasonic examination referred to in this specification is intended to detect longitudinal discontinuities having a reflective area similar to or larger than the reference notch. The examination may not detect circumferentially oriented imperfections or short, deep defects.

9.2.2 The eddy-current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short, abrupt type.

9.2.3 The hydrostatic test referred to in Section 8 is a test method provided for in many product specifications. This test has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall defects or defects that extend an appreciable distance into the wall without complete penetration.

9.2.4 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

9.3 In order to accommodate the various types of nondestructive electric testing equipment and techniques in use, the calibration tube shall contain, at the option of the producer, any one or more of the following discontinuities to establish a minimum sensitivity level for rejection.

9.3.1 *Drilled Hole*—Drill a hole radially and completely through the pipe wall, care being taken to avoid distortion of the pipe while drilling. The diameter of the hole shall not be larger than 0.031 in. [0.8 mm] for pipe under 0.125 in. [3.2 mm] in wall thickness, not larger than 0.0625 in. [1.6 mm] for pipe between 0.125 in. [3.2 mm] and 0.200 in. [5.0 mm] in wall thickness, and not larger than 0.125 in. [3.2 mm] for pipe over 0.200 in. [5.0 mm] in wall thickness.

9.3.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼-in. [6-mm] diameter, file or mill a notch tangential to the surface and transverse to the longitudinal axis of the pipe. The notch shall have a depth not exceeding 12½ % of the specified wall thickness of the pipe.

9.3.3 *Longitudinal Notch*—Machine a notch 0.031 in. [0.8 mm] or less in width in a radial plane parallel to the pipe axis on the outside surface of the pipe, to have a depth not exceeding 12½ % of the specified wall thickness of the pipe. The length of the notch shall be compatible with the testing method.

9.3.4 *Compatibility*—The discontinuity in the calibration pipe shall be compatible with the testing equipment and method being used.

9.4 Reject pipe producing a signal equal to or greater than the calibration discontinuity.

10. Flattening Test

10.1 Perform the flattening test on pipe in accordance with the following:

10.1.1 *Electric-Resistance-Welded Pipe*—Flatten a specimen at least 4 in. [100 mm] in length cold between paralleled plates in three steps with the weld located either 0 or 90° from the line of direction of force as required in 10.1.1.1. During the first step, a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than two thirds of the original outside diameter of the pipe. As a second step, continue the flattening. During the second step, a test for the ductility exclusive of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than one third of the original outside diameter of the pipe, but is not less than five times the wall thickness of the pipe. During the third step, a test for soundness, continue the flattening until the specimen breaks or the opposite walls of the specimen meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

10.1.1.1 For pipe produced in single lengths, perform the flattening test specified in 10.1.1 on both crop ends from each length of pipe. Alternate the tests from each end with the weld at 0° and at 90° from the line of direction of force. For pipe produced in multiple lengths, perform the flattening test on crop ends representing the front and back of each coil with the weld at 90° from the line of direction of force, and on two intermediate rings representing each coil with the weld 0° from the line of direction of force.

10.1.1.2 For pipe that is to be subsequently reheated throughout its cross section and hot formed by a reducing process, the manufacturer shall have the option of obtaining the flattening test specimens required by 10.1.1.1 either prior to or after such hot reducing.

10.1.2 *Furnace-Welded Pipe*—For furnace-welded pipe, flatten a specimen not less than 4 in. [100 mm] in length cold between parallel plates in three steps. Locate the weld 90° from the line of the direction of force. During the first step, a test for quality of the weld, no cracks or breaks on the inside, outside, or end surfaces shall occur until the distance between the plates is less than three fourths of the original outside diameter of the pipe. As a second step, continue the flattening. During the second step, a test for ductility exclusive of the weld, no cracks or breaks on the inside, outside, or end surfaces shall occur until the distance between the plates is less than 60 % of the original outside diameter of the pipe. During the third step, a test for soundness, continue the flattening until the specimen breaks or the opposite walls of the specimen meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test, shall be cause for rejection.

10.2 Surface imperfections in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the workmanship requirements in Section 15.

10.3 Superficial ruptures as a result of surface imperfections shall not be cause for rejection.

11. Coating

11.1 Galvanized pipe shall be coated with zinc inside and outside by the hot-dip process. The zinc used for the coating shall be any grade of zinc conforming to Specification B 6.

11.2 *Weight of Coating*:

11.2.1 The weight of the zinc coating shall not be less than 1.5 oz/ft^2 [0.46 kg/m^2] as determined from the average of two specimens tested in accordance with 16.1 and not less than 1.3 oz/ft^2 [0.40 kg/m^2] for either of the specimens. The weight of coating expressed in ounces per square foot or kilograms per square metre shall be calculated by dividing the total weight of zinc, inside plus outside, by total area, inside plus outside, of the surface coated.

11.2.2 Test specimens for the determination of weight of coating shall be cut approximately 4 in. [100 mm] in length.

11.2.3 Determine the weight of zinc coating by a stripping test in accordance with Test Method A 90/A 90M. The total zinc on each specimen shall be determined in a single stripping operation.

11.2.4 If flattening tests are made on galvanized samples, any flaking or cracking of the galvanized coating shall not be cause for rejection.

11.3 *Protective Coating*—If required by the purchaser, the pipe shall be cleaned of all foreign matter, dried, and given a protective coating such as oil, lacquer, enamel, etc., as agreed upon by the purchaser.

12. Lengths

12.1 Unless otherwise specified, pipe shall be furnished in single random lengths of 16 to 22 ft [4.9 to 6.7 m].

13. Weights

13.1 The weights with the corresponding wall thicknesses for pipe of various outside diameters are prescribed in Table 1 and Table 2.

13.2 Nipples shall be cut from pipe of the same quality and the same or heavier weight described in 13.1.

14. Dimensions, Weight, and Permissible Variations

14.1 *Weight*—For the pipe covered by Table 1 and Table 2, the weight shall not vary more than ± 5 % from that prescribed. The weight of pipe having other wall thicknesses shall not vary more than ± 5 % from the nominal weight calculated from the relevant equations in Section 5 of ASME B36.10M.

NOTE 6—The weight tolerance of ± 5 % is determined from the weights of customary lifts of pipe as produced for shipment by the mill divided by the total length in the lift. On pipe sizes over NPS 4 [DN 100], where individual lengths may be weighed, the weight tolerance is applicable to the individual length.

14.2 *Diameter*—For pipe NPS 1½ [DN 40] and under, the outside diameter at any point shall not vary more than ± 1⁄64 in. (0.016 in.) [0.41 mm] from the specified outside diameter. For pipe NPS 2 [DN 50] and over, the outside diameter shall not vary more than ± 1 % from the specified outside diameter.

14.3 *Thickness*—The minimum wall thickness at any point shall not vary more than 12.5 % under the nominal wall thickness.

15. Workmanship, Finish, and Appearance

15.1 The finished pipe shall be reasonably straight and free of defects. Any imperfection having a depth greater than 12½ % of the specified wall thickness, measured from the surface of the pipe, shall be considered a defect. All burrs at the pipe ends shall be removed.

15.2 *End Finish*—Pipe shall conform to the following practice:

15.2.1 Each end of pipe shall be furnished plain end unless otherwise specified.

15.2.2 When threads are specified, all threads shall be in accordance with the gaging practice and tolerances of ASME B1.20.1.

15.2.3 When couplings are specified, they shall be manufactured in accordance with Specification A 865.

16. Number of Tests

16.1 Two test specimens for the determination of weight of coating shall be taken, one from each end of one length of galvanized pipe, selected at random from each lot of 500 lengths, or fraction thereof, of each size.

16.2 Each length of pipe shall be subjected to one of the tests specified in Section 8 or 9.

16.3 For electric-resistance-welded pipe, tests specified in 10.1.1 shall be made.

16.4 For furnace-welded pipe, the tests specified in 10.1.2 shall be made on one length of pipe from each lot of 25 tons, or fraction thereof, of pipe NPS 1½ [DN 40] and smaller, and from each lot of 50 tons, or fraction thereof, of pipe NPS 2 [DN 50] and larger.

17. Retests

17.1 If the weight of coating of any lot does not conform to the requirements specified in 11.2, retests of two additional pipe from the same lot shall be made, each of which shall conform to the requirements specified.

17.2 If any section of furnace-butt-welded pipe fails to comply with the requirements of 10.1.2, double the number of tests shall be made, after having rejected the length(s) that exhibit failure. Each of the retests shall conform to the requirements specified.

17.3 If any section of electric-resistance-welded pipe NPS 4 [DN 100] or less fails to comply with the requirements of 10.1.1 for pipe produced in multiple lengths, double the number of tests shall be made, after having rejected the length(s) that exhibit failure. Each of the retests shall conform to the requirements specified.

17.4 If any section of electric-resistance-welded pipe larger than NPS 4 [DN 100] fails to comply with the requirements of 10.1.1 for pipe produced in single lengths, other sections may be cut from the same end of the same length until satisfactory tests are obtained, except that the finished pipe shall not be shorter than 80 % of its length after the original cropping; otherwise the length shall be rejected. For pipe produced in multiple lengths, retests may be cut from each end of each individual length in the multiple. Such tests shall be made with the weld alternately 0° and 90° from the line of direction of force. Each length that exhibits failure shall be rejected.

18. Inspection

18.1 The inspector representing the purchaser shall have free entry at all times while work is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

18.2 *For Government Procurement Only*— Except as otherwise specified in the contract, the contractor is responsible for the performance of all inspection and test requirements specified herein and may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser at the time of purchase. The purchaser shall have the right to perform any of the inspections and tests at the same frequency as set forth in this specification, where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

19. Rejection

19.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test methods as outlined herein, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

19.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be the subject of a mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both conditions involved. Disposition shall be a matter of agreement.

20. Certification

20.1 The producer or supplier shall, upon request, furnish to the purchaser a certificate of inspection stating that the material has been manufactured, sampled, tested, and inspected in accordance with this specification, and has been found to meet the requirements.

21. Product Marking

21.1 Each length of pipe shall be legibly marked by rolling, stamping, or stenciling to show the name or brand of the manufacturer, the kind of pipe, that is, continuous-welded, electric-resistance-welded A, electric-resistance-welded B, seamless A, or seamless B. Grade A or B for Type E or S pipe, the ASTM designation, the length, and the letters "NH" if not hydrostatically tested. Bundled pipe NPS 1½ [DN 40] and smaller may have this information marked on a tag, securely attached to each bundle.

21.2 When pipe sections are cut into shorter lengths by a subsequent processor for resale as material, the processor shall transfer complete identifying information to each unmarked cut length, or to metal tags securely attached to bundles of unmarked small diameter pipe. The same material designation shall be included with the information transferred and the processor's name, trademark, or brand shall be added.

21.3 *Bar Coding*—In addition to the requirements in 21.1 and 21.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

22. Packaging, Package Marking, and Loading

22.1 When specified in the purchase order, packaging, marking, and loading of shipment shall be in accordance with those procedures of Practices A 700.

22.2 *For Government Procurement*—When specified in the contract or purchase order, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract or order. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 and MIL-STD-129 for military agencies.

23. Keywords

23.1 black steel pipe; seamless steel pipe; steel pipe; welded steel pipe; zinc coated steel pipe

ANNEX

(Mandatory Information)

A1. DEFINITIONS OF TYPES OF PIPE

A1.1 *Type F, Furnace-Welded Pipe, Continuous-Welded*—Pipe produced in continuous lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt-joint forge welded by the mechanical pressure developed in rolling the hot-formed skelp through a set of round pass welding rolls.

A1.2 *Type E, Electric-Resistance-Welded Pipe*—Pipe produced in individual lengths or in continuous lengths from coiled skelp (flat-rolled product) and subsequently cut into individual lengths, having a longitudinal butt joint wherein coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which the pipe is a part, and by the application of pressure. Included in this category are induction welded or RF-welded pipe.

A1.3 *Type S, Wrought Steel Seamless Pipe*—Wrought steel seamless pipe is a tubular product made without a welded seam. It is manufactured by hot working steel and, if necessary, by subsequently cold finishing the hot-worked tubular product to produce the desired shape, dimensions, and properties.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 795/A 795M – 04, that may impact the use of this specification. (Approved July 1, 2007)

(*1*) Revised 14.2.

Designation: A 790/A 790M – 07

Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe[1]

This standard is issued under the fixed designation A 790/A 790M; 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 seamless and straight-seam welded ferritic/austenitic steel pipe intended for general corrosive service, with particular emphasis on resistance to stress corrosion cracking. These steels are susceptible to embrittlement if used for prolonged periods at elevated temperatures.

1.2 Optional supplementary requirements are provided for pipe when a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, one or more of these may be specified in the order.

1.3 Appendix X1 of this specification lists the dimensions of welded and seamless stainless steel pipe as shown in ANSI B36.19. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

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 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]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

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 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys

E 527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *ANSI Standards:*[4]

B1.20.1 Pipe Threads, General Purpose

B36.10 Welded and Seamless Wrought Steel Pipe

B36.19 Stainless Steel Pipe

2.3 *SAE Standard:*[5]

SAE J 1086

2.4 *Other Standard:*[6]

SNT-TC-1A Personal Qualification and Certification in Nondestructive Testing

2.5 *AWS Standard*

A5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Electrodes

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification refer to Terminology A 941.

4. Ordering Information

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

4.1.1 Quantity (feet, [metres], or number of lengths),

[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.

Current edition approved Sept. 1, 2007. Published October 2007. Originally approved in 1981. Last previous edition approved in 2005 as A 790/A 790M – 05b.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA–790 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 National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

[6] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

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

4.1.2 Name of material (ferritic/austenitic steel pipe),
4.1.3 Process (seamless or welded),
4.1.4 Grade (see Table 1),
4.1.5 Size (NPS designator or outside diameter and schedule number of average wall thickness),
4.1.6 Length (specific or random) (see Section 11),
4.1.7 End finish (section on ends of Specification A 999/A 999M),
4.1.8 Optional requirements (product analysis, Section 9; hydrostatic test or nondestructive electric test, Section 14),
4.1.9 Test report required (section on certification of Specification A 999/A 999M),
4.1.10 Specification designation, and
4.1.11 Special requirements and any supplementary requirements selected.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

6. Materials and Manufacture

6.1 *Manufacture*:

6.1.1 The pipe shall be made by the seamless or an automatic welding process, with no addition of filler metal in the welding operation.

6.1.2 At the manufacturer's option, pipe may be either hot-finished or cold-finished.

6.1.3 The pipe shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

6.2 *Discard*—A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

6.3 All pipe shall be furnished in the heat-treated condition as shown in Table 1. For seamless pipe, as an alternate to final heat treatment in a continuous furnace or batch-type furnace, immediately following hot forming while the temperature of the pipes is not less than the specified minimum solution treatment temperature, pipes shall be individually quenched in water or rapidly cooled by other means, except for UNS S32950, which shall be air cooled.

7. Chemical Composition

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

TABLE 1 Heat Treatment

UNS Designation	Type[A]	Temperature °F [°C]	Quench
S31200		1920–2010 [1050–1100]	Rapid cooling in water
S31260		1870–2010 [1020–1100]	Rapid cooling in air or water
S31500		1800–1900 [980–1040]	Rapid cooling in air or water
S31803		1870–2010 [1020–1100]	Rapid cooling in air or water
S32003		1850–2050 [1010–1120]	Rapid cooling in air or water
S32101		1870 [1020]	Quenched in water or rapidly cooled by other means
S32205	2205	1870–2010 [1020–1100]	Rapid cooling in air or water
S32304	2304	1700–1920 [925–1050]	Rapid cooling in air or water
S32506		1870–2050 [1020–1120]	Rapid cooling in air or water
S32520		1975–2050 [1080–1120]	Rapid cooling in air or water
S32550	255	1900 [1040] min	Rapid cooling in air or water
S32707		1975–2050 [1080–1120]	Rapid cooling in air or water
S32750	2507	1880–2060 [1025–1125]	Rapid cooling in air or water
S32760		2010–2085 [1100–1140]	Rapid cooling in air or water
S32808		1920–2100 [1050–1150]	Rapid cooling in air or water
S32900	329	1700–1750 [925–955]	Rapid cooling in air or water
S32906		1870–2100 [1020–1150]	Rapid cooling in air or water
S32950		1820–1880 [990–1025]	Air cool
S39274		1920–2060 [1025–1125]	Rapid cooling in air or water
S39277		1975–2155 [1080–1180]	Rapid cooling in air or water

[A]Common name, not a trademark, widely used, not associated with any one producer. 329 is na AISI number.

TABLE 2 Chemical Requirements[A]

UNS Designation[B]	Type[C]	C	Mn	P	S	Si	Ni	Cr	Mo	N	Cu	Others
S31200		0.030	2.00	0.045	0.030	1.00	5.5–6.5	24.0–26.0	1.20–2.00	0.14–0.20	. . .	. . .
S31260		0.030	1.00	0.030	0.030	0.75	5.5–7.5	24.0–26.0	2.5–3.5	0.10–0.30	0.20–0.80	W 0.10–0.50
S31500		0.030	1.20–2.00	0.030	0.030	1.40–2.00	4.2–5.2	18.0–19.0	2.50–3.00	0.05–0.10	. . .	. . .
S31803		0.030	2.00	0.030	0.020	1.00	4.5–6.5	21.0–23.0	2.5–3.5	0.08–0.20	. . .	. . .
S32003		0.030	2.00	0.030	0.020	1.00	3.0–4.0	19.5-22.5	1.50–2.00	0.14–0.20	. . .	. . .
S32101		0.040	4.0–6.0	0.040	0.030	1.00	1.35–1.70	21.0–22.0	0.10–0.80	0.20–0.25	0.10–0.80	. . .
S32205	2205	0.030	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5	0.14–0.20	. . .	. . .
S32304	2304	0.030	2.50	0.040	0.040	1.00	3.0–5.5	21.5–24.5	0.05–0.60	0.05–0.20	0.05–0.60	. . .
S32506		0.030	1.00	0.040	0.015	0.90	5.5–7.2	24.0–26.0	3.0–3.5	0.08–0.20	. . .	W 0.05–0.30
S32520		0.030	1.5	0.035	0.020	0.80	5.5–8.0	24.0–26.0	3.0–5.0	0.20–0.35	0.5–3.00	. . .
S32550	255	0.04	1.50	0.040	0.030	1.00	4.5–6.5	24.0–27.0	2.9–3.9	0.10–0.25	1.50–2.50	. . .
S32707		0.030	1.50	0.035	0.010	0.50	5.5–9.5	26.0–29.0	4.0–5.0	0.30–0.50	1.0	Co 0.5–2.0
S32750	2507	0.030	1.20	0.035	0.020	0.80	6.0–8.0	24.0–26.0	3.0–5.0	0.24–0.32	0.5	. . .
S32760		0.05	1.00	0.030	0.010	1.00	6.0–8.0	24.0–26.0	3.0–4.0	0.20–0.30	0.50–1.00	W 0.50–1.00 40 min[D]
S32808		0.030	1.10	0.030	0.030	0.50	7.0–8.2	27.0–27.9	0.80–1.20	0.30–0.40	. . .	W 2.10–2.50
S32900	329	0.08	1.00	0.040	0.030	0.75	2.5–5.0	23.0–28.0	1.00–2.00	. . .	. . .	. . .
S32906		0.030	0.80–1.50	0.030	0.030	0.80	5.8–7.5	28.0–30.0	1.50–2.60	0.30–0.40	0.80	. . .
S32950		0.030	2.00	0.035	0.010	0.60	3.5–5.2	26.0–29.0	1.00–2.50	0.15–0.35	. . .	. . .
S39274		0.030	1.00	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.5–3.5	0.24–0.32	0.20–0.80	W 1.50–2.50
S39277		0.025	0.80	0.025	0.002	0.80	6.5–8.0	24.0–26.0	3.0–4.0	0.23–0.33	1.20–2.00	W 0.8–1.2

[A] Maximum, unless a range or minimum is indicated. Where ellipses (...) appear in this table, there is no minimum and analysis for the element need not be determined or reported.

[B] New designation established in accordance with Practice E 527 and SAE J 1086.

[C] Common name, not a trademark, widely used, not associated with any one producer. 329 is na AISI number.

[D] % Cr + 3.3 × % Mo + 16 × % N.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified.

9. Product Analysis

9.1 At the request of the purchaser's inspector, an analysis of one billet or one length of flat-rolled stock from each heat, or two pipes from each lot, shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel:

NPS Designator	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5, incl	200 or fraction thereof
6 and over	100 or fraction thereof

9.2 The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Section 7.

9.3 If the analysis of one of the tests specified in 8.1 or 9.1 does not conform to the requirements specified in Section 7, 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.

10. Tensile and Hardness Properties

10.1 The material shall conform to the tensile and hardness properties prescribed in Table 3.

11. Lengths

11.1 Pipe lengths shall be in accordance with the following regular practice:

11.1.1 Unless otherwise agreed upon, all sizes from NPS ⅛ to and including NPS 8 are available in a length up to 24 ft (see Note 2) with the permissible range of 15 to 24 ft (see Note 2). Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

TABLE 3 Tensile and Hardness Requirements

UNS Designation	Type[A]	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Hardness, max	
					HBW	HRC
S31200		100 [690]	65 [450]	25	280	. . .
S31260		100 [690]	65 [450]	25	. . .	. . .
S31500		92 [630]	64 [440]	30	290	30
S31803		90 [620]	65 [450]	25	290	30
S32003		90 [620]	65 [450]	25	290	30
S32101						
t ≤ 0.187 in. [5.00 mm]		101 [700]	77 [530]	30	290	. . .
t > 0.187 in. [5.00 mm]		94 [650]	65 [450]	30	290	. . .
S32205	2205	95 [655]	65 [450]	25	290	30
S32304	2304	87 [600]	58 [400]	25	290	30
S32506		90 [620]	65 [450]	18	302	32
S32520		112 [770]	80 [550]	25	310	. . .
S32550	255	110 [760]	80 [550]	15	297	31
S32707		133 [920]	101 [700]	25	318	34
S32750	2507	116 [800]	80 [550]	15	300	32
S32760[B]		109 [750]	80 [550]	25	270	. . .
S32808		116 [800]	80 [550]	15	310	32
S32900	329	90 [620]	70 [485]	20	271	28
S32906						
Wall below 0.40 in. [10 mm]		116 [800]	94 [650]	25	300	32
Wall 0.40 in. [10 mm] and above		109 [750]	80 [550]	25	300	32
S32950		100 [690]	70 [480]	20	290	30
S39274		116 [800]	80 [550]	15	310	. . .
S39277		120 [825]	90 [620]	25	290	30

[A]Common name, not a trademark, widely used, not associated with any one producer. 329 is na AISI number.
[B] Prior to A 790/A 790M – 04, the tensile strength value for UNS 32760 was 109–130 ksi [750–895 MPa].

NOTE 2—This value 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.

11.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be less than the specified length and no more than ¼ in. [6 mm] over it.

11.1.3 No jointers are permitted unless otherwise specified.

12. Workmanship, Finish, and Appearance

12.1 The finished pipes shall be reasonably straight and shall have a workmanlike finish. Imperfections may be removed by grinding, provided the wall thicknesses are not decreased to less than that permitted, in the Permissible Variations in Wall Thickness Section of Specification A 999/A 999M.

13. Mechanical Tests Required

13.1 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from 2 pipes for lots of more than 100 pipes.

13.2 *Mechanical Testing Lot Definition* —The term *lot* for mechanical tests 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 as defined as follows:

13.2.1 Where the heat treated condition is obtained, consistent with the requirements of 6.3, in a continuous heat treatment furnace or by directly obtaining the heat treated condition by quenching after hot forming, the lot shall include all pipe of the same size and heat, heat treated in the same furnace at the same temperature, time at heat, and furnace speed or all pipe of the same size and heat, hot formed and quenched in the same production run.

13.2.2 Where final heat treatment is obtained, consistent with the requirements of 6.3, in a batch-type heat-treatment furnace equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or smaller range, the lot shall be the larger of (a) each 200 ft [60 m] or fraction thereof or (b) that pipe heat treated in the same batch furnace charge.

13.2.3 Where the final heat treatment is obtained, consistent with the requirements of 6.3, in a batch-type heat-treatment furnace not equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or smaller range, the term *lot* for mechanical tests applies to the pipe heat treated in the same batch furnace charge, provided that such pipe is of the same nominal size and wall thickness (or schedule) and is produced from the same heat of steel.

13.3 *Flattening Test*—For pipe heat treated in a batch-type furnace, flattening tests shall be made on 5 % of the pipe from each heat-treated lot. For pipe heat treated by the continuous process, or by direct quenching after hot forming, this test shall be made on a sufficient number of pipes to constitute 5 % of the lot, but in no case less than two lengths of pipe.

13.3.1 For welded pipe with a diameter equal to or exceeding NPS 10, a transverse guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A 370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5 % of the lot shall be taken from the pipes or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

13.4 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two pipes from each lot (see 13.2).

14. Hydrostatic or Nondestructive Electric Test

14.1 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.

14.2 The hydrostatic test shall be in accordance with Specification A 999/A 999M, except that the value for S to be used in the calculation of the hydrostatic test pressure shall be equal to 50 % of the specified minimum yield strength of the pipe.

14.3 *Nondestructive Electric Test*:

Nondestructive electric tests shall be in accordance with Practices E 213 or E 309.

14.3.1 As an alternative to the hydrostatic test, and when specified by the purchaser, each pipe shall be examined with a nondestructive test in accordance with Practices E 213 or E 309. Unless specifically called out by the purchaser, the selection of the nondestructive electric test will be at the option of the manufacturer. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

14.3.1.1 The following information is for the benefit of the user of this specification:

14.3.1.2 The reference standards defined in 14.3.1.3-14.3.1.5 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

14.3.1.3 The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep, defects.

14.3.1.4 The eddy-current testing (ET) referenced in this specification (see Practice E 426) has the capability of detecting significant discontinuities, especially the short abrupt type.

14.3.1.5 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

14.4 *Time of Examination*—Nondestructive testing for specification acceptance shall be performed after all mechanical processing, heat treatments, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

14.5 *Surface Condition*:

14.5.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

14.5.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

14.6 *Extent of Examination*:

14.6.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except as in 14.6.2.

14.6.2 The existence of end effects is recognized and the extent of such effects shall be determined by the manufacturer and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

14.7 *Operator Qualifications*—The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent recognized and documented standard.

14.8 *Test Conditions*:

14.8.1 For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide good signal-to-noise ratio.

14.8.2 The maximum eddy-current coil frequency used shall be as follows:

On specified walls up to 0.050 in.—100 KHz max
On specified walls up to 0.150 in.—50 KHz max
On specified walls over 0.150 in.—10 KHz max

14.8.3 *Ultrasonic*—For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.00 MHz and the maximum nominal transducer size shall be 1.5 in. If the equipment contains a reject notice filter setting, this shall remain off during calibration and testing unless linearity can be demonstrated at that setting.

14.9 *Reference Standards*—Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS, or outside diameter and schedule or wall thickness), surface finish and heat treatment condition as the pipe to be examined.

14.9.1 *For Ultrasonic Testing*, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of each notch shall not exceed 12 ½ % of the specified nominal wall thickness of the pipe or 0.004 in., whichever is greater. The width of the notch shall not exceed twice the depth. Notches shall be placed on both the OD and ID surfaces.

14.9.2 *For Eddy-Current Testing*, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

14.9.2.1 *Drilled Hole*— The reference standard shall contain three or more holes equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. One hole shall be drilled in the weld, if visible. Alternately, the producer of welded pipe may choose to drill one hole in the weld and run the calibration standard through the test coils three times with the weld turned at 120° on each pass. The hole diameter shall vary with NPS as follows:

NPS Designator	Hole Diameter
	0.039 in. [1 mm]
above ½ to 1¼	0.055 in. [1.4 mm]
above 1¼ to 2	0.071 in. [1.8 mm]
above 2 to 5	0.087 in. [2.2 mm]
above 5	0.106 in. [2.7 mm]

14.9.2.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼-in. [6.4-mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding 12 ½ % of the specified nominal wall thickness of the pipe or 0.004 in. [0.102 mm], whichever is greater.

14.9.2.3 *Longitudinal Notch*—A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe to have a depth not exceeding 12 ½ % of the specified wall thickness of the pipe or 0.004 in., whichever is greater. The length of the notch shall be compatible with the testing method.

More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

14.10 *Standardization Procedure*:

14.10.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness, grade, and heat treatment condition), and at intervals not exceeding 4 h. More frequent standardization may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

14.10.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss, process shutdown, or when a problem is suspected.

14.10.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the pipe to be tested.

14.10.4 The signal-to-noise ratio for the reference standard shall be 2 ½ to 1 or greater. Extraneous signals caused by identifiable causes such as dings, scratches, dents, straightener marks, and so forth shall not be considered noise. The rejection amplitude shall be adjusted to be at least 50 % of full scale of the readout display.

14.10.5 If upon any standardization, the rejection amplitude has decreased by 29 % (3 dB) of peak height from the last standardization, the pipe since the last calibration shall be rejected. The test system settings may be changed or the transducer(s), coil(s), or sensor(s) adjusted and the unit restandardized. But all pipe tested since the last acceptable standardization must be retested for acceptance.

14.11 *Evaluation of Imperfections*:

14.11.1 Pipes producing a signal equal to or greater than the lowest signal produced by the reference standard(s) shall be identified and separated from the acceptable pipes. The area producing the signal may be reexamined.

14.11.2 Such pipes shall be rejected if the test signal was produced by imperfections that cannot be identified or was produced by cracks or crack-like imperfections. These pipes may be repaired per Sections 12 and 13. To be accepted, a repaired pipe must pass the same non-destructive test by which it was rejected, and it must meet the minimum wall thickness requirements of this specification.

14.11.3 If the test signals were produced by visual imperfections such as: (*1*) scratches, (*2*) surface roughness, (*3*) dings, (*4*) straightener marks, (*5*) cutting chips, (*6*) steel die stamps, (*7*) stop marks, or (*8*) pipe reducer ripple. The pipe may be accepted based on visual examination, provided the imperfection is less than 0.004 in. [0.1 mm] or 12 ½ % of the specified wall thickness (whichever is greater).

14.11.4 Rejected pipe may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed. To be accepted, retested pipe shall meet the test requirement.

14.11.5 If the imperfection is explored to the extent that it can be identified as non-rejectable, the pipe may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness.

15. Repair by Welding

15.1 For welded pipe of size NPS 6 or larger with a specified wall thickness of 0.188 in. [4.8 mm] or more, weld repairs made with the addition of compatible filler metal may be made to the weld seam with the same procedures specified for plate defects in the section on Repair by Welding of Specification A 999/A 999M.

15.2 Weld repairs of the weld seam shall not exceed 20 % of the seam length.

15.3 Except as allowed by 15.3.1, weld repairs shall be made only with the gas tungsten-arc welding process using the same classification of bare filter rod qualified to the most current AWS Specification A5.9 as the grade of pipe being repaired as given in Table 4.

TABLE 4 Pipe and Filler Metal Specification

Pipe	Filler Metal	
UNS Designation	AWS A5.9 Class	UNS Designation
S31803	ER2209	S39209
S32205	ER2209	S39209
S31200	ER2553	S39553

15.3.1 Subject to approval by the purchaser, it shall be permissible for weld repairs to be made with the gas tungsten-arc welding process using a filler metal more highly alloyed than the base metal, if needed for corrosion resistance or other properties.

15.4 Pipes that have had weld seam repairs with filler metal shall be identified with the symbol "WR" and shall be so stated and identified on the certificate of tests. If filler metal other than that listed in Table 4 is used, the filler metal shall be identified on the certificate of tests.

15.5 Weld repairs shall be completed prior to any heat treatment.

16. Product Marking

16.1 In addition to the marking prescribed in Specification A 999/A 999M, the marking shall include the manufacturer's private identifying mark and whether the pipe is seamless or welded. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

17. Keywords

17.1 duplex stainless steel; ferritic/austenitic stainless steel; seamless steel pipe; stainless steel pipe; steel pipe; welded steel pipe

SUPPLEMENTARY REQUIREMENTSFOR PIPE REQUIRING SPECIAL CONSIDERATION

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe over NPS 5 there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 7 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This applies only to pipe over NPS 8.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one end or both ends of each pipe. Crops ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

APPENDIX

(Nonmandatory Information)

X1. Table X1.1 IS BASED ON TABLE 1 OF THE AMERICAN NATIONAL STANDARD FOR STAINLESS STEEL PIPE (ANSI B36.19-1965)

TABLE X1.1 Dimensions of Welded and Seamless Stainless Steel Pipe

NOTE 1—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
			Schedule 5S[A]		Schedule 10S[A]		Schedule 40S		Schedule 80S	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
1⁄8	0.405	10.29	. . .	. . .	0.049[B]	1.24	0.068	1.73	0.095	2.41
1⁄4	0.540	13.72	. . .	. . .	0.065[B]	1.65	0.088	2.24	0.119	3.02
3⁄8	0.675	17.15	. . .	. . .	0.065[B]	1.65	0.091	2.31	0.126	3.20
1⁄2	0.840	21.34	0.065[B]	1.65	0.083[B]	2.11	0.109	2.77	0.147	3.73
3⁄4	1.050	26.67	0.065[B]	1.65	0.083[B]	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065[B]	1.65	0.109[B]	2.77	0.133	3.38	0.179	4.55
1 1⁄4	1.660	42.16	0.065[B]	1.65	0.109[B]	2.77	0.140	3.56	0.191	4.85
1 1⁄2	1.900	48.26	0.065[B]	1.65	0.109[B]	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065[B]	1.65	0.109[B]	2.77	0.154	3.91	0.218	5.54
2 1⁄2	2.875	73.03	0.083	2.11	0.120[B]	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120[B]	3.05	0.216	5.49	0.300	7.62
3 1⁄2	4.000	101.60	0.083	2.11	0.120[B]	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120[B]	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109[B]	2.77	0.134[B]	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134[B]	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109[B]	2.77	0.148[B]	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134[B]	3.40	0.165[B]	4.19	0.365	9.27	0.500[B]	12.70[B]
12	12.750	323.85	0.156[B]	3.96	0.180[B]	4.57	0.375[B]	9.52[B]	0.500[B]	12.70[B]
14	14.000	355.60	0.156[B]	3.96	0.188	4.78	. . .	. . .	. . .	. . .
16	16.000	406.40	0.165[B]	4.19	0.188	4.78	. . .	. . .	. . .	. . .
18	18.000	457.20	0.165[B]	4.19	0.188	4.78	. . .	. . .	. . .	. . .
20	20.000	508.00	0.188[B]	4.78	0.218[B]	5.54	. . .	. . .	. . .	. . .
22	22.000	558.80	0.188[B]	4.78	0.218[B]	5.54	. . .	. . .	. . .	. . .
24	24.000	609.60	0.218[B]	5.54	0.250	6.35	. . .	. . .	. . .	. . .
30	30.000	762.00	0.250	6.35	0.312	7.92	. . .	. . .	. . .	. . .

[A] Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).
[B] These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10-1979).

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 790/A 790M – 05b, that may impact the use of this specification. (Approved September 1, 2007)

(*1*) Added common names to Tables 1-3.

(*2*) Added new duplex grade, S32506, to Tables 1-3.

Designation: A 789/A 789M – 05b

Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service[1]

This standard is issued under the fixed designation A 789/A 789M; 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 grades of nominal wall thickness, stainless steel tubing for services requiring general corrosion resistance, with particular emphasis on resistance to stress corrosion cracking. These steels are susceptible to embrittlement if used for prolonged periods at elevated temperatures.

1.2 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:* [3]

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *SAE Standard:*[4]

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

3. Ordering Information

3.1 Orders for product 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 product (seamless or welded tubes),

3.1.3 Grade (see Table 1),

3.1.4 Size (outside diameter and nominal wall thickness),

3.1.5 Length (specific or random),

3.1.6 Optional requirements (for product analysis, see Section 8; for hydrostatic or nondestructive electric test, see Section 10),

3.1.7 Test report required (see the Inspection section of Specification A 1016/A 1016M),

3.1.8 Specification designation, and

3.1.9 Special requirements.

4. General Requirements

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

5. Manufacture

5.1 The tubes shall be made by the seamless or welded process with no filler metal added.

6. Heat Treatment

6.1 All tubes shall be furnished in the heat-treated condition in accordance with the procedures shown in Table 2. For seamless tubes, as an alternate to final heat treatment in a continuous furnace or batch-type furnace, immediately following hot forming while the temperature of the tubes is not less than the specified minimum solution treatment temperature, tubes may be individually quenched in water or rapidly cooled by other means.

[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.

Current edition approved September 1, 2005. Published September 2005. Originally approved in 1981. Last previous edition approved in 2005 as A 789/A 789M–05a.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA–789 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 Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

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

TABLE 1 Chemical Requirements[A]

UNS Designation[B]	C	Mn	P	S	Si	Ni	Cr	Mo	N	Cu	Others
S31200	0.030	2.00	0.045	0.030	1.00	5.5–6.5	24.0–26.0	1.20–2.00	0.14–0.20	. . .	. . .
S31260	0.030	1.00	0.030	0.030	0.75	5.5–7.5	24.0–26.0	2.5–3.5	0.10–0.30	0.20–0.80	W 0.10–0.50
S31500	0.030	1.20–2.00	0.030	0.030	1.40–2.00	4.3–5.2	18.0–19.0	2.50–3.00	0.05–0.1	. . .	. . .
S31803	0.030	2.00	0.030	0.020	1.00	4.5–6.5	21.0–23.0	2.5–3.5	0.08–0.20	. . .	. . .
S32001	0.030	4.00–6.00	0.040	0.030	1.00	1.0–3.0	19.5–21.5	0.60	0.05–0.17	1.00	. . .
S32003	0.030	2.00	0.030	0.020	1.00	3.0-4.0	19.5-22.5	1.50-2.00	0.14-0.20	. . .	. . .
S32101	0.040	4.0-6.0	0.040	0.030	1.00	1.35-1.70	21.0-22.0	0.10-0.80	0.20-0.25	0.10-0.80	. . .
S32205	0.030	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5	0.14–0.20	. . .	. . .
S32304	0.030	2.50	0.040	0.040	1.00	3.0–5.5	21.5–24.5	0.05–0.60	0.05–0.20	0.05–0.60	. . .
S32520	0.030	1.50	0.035	0.020	0.80	5.5–8.0	23.0–25.0	3.–5.	0.20–0.35	0.50–3.00	. . .
S32550	0.04	1.50	0.040	0.030	1.00	4.5–6.5	24.0–27.0	2.9–3.9	0.10–0.25	1.50–2.50	. . .
S32707	0.030	1.50	0.035	0.010	0.50	5.5–9.5	26.0–29.0	4.0–5.0	0.30–0.50	1.0 max	Co 0.5–2.0
S32750	0.030	1.20	0.035	0.020	0.80	6.0–8.0	24.0–26.0	3.0–5.0	0.24–0.32	0.50	. . .
S32760	0.05	1.00	0.030	0.010	1.00	6.0–8.0	24.0–26.0	3.0–4.0	0.20–0.30	0.50–1.00	W 0.50–1.00 40 min[C]
S32808	0.030	1.10	0.030	0.030	0.50	7.0–8.2	27.0–27.9	0.80–1.20	0.30–0.40	. . .	W 2.10–2.50
S32900	0.08	1.00	0.040	0.030	0.75	2.5–5.0	23.0–28.0	1.00–2.00	. . .	. . .	. . .
S32906	0.030	0.80–1.50	0.030	0.030	0.80	5.8–7.5	28.0 –30.0	1.50–2.60	0.30–0.40	0.80	. . .
S32950	0.030	2.00	0.035	0.010	0.60	3.5–5.2	26.0–29.0	1.00–2.50	0.15–0.35	. . .	. . .
S39274	0.030	1.00	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.5–3.5	0.24–0.32	0.20–0.80	W 1.50–2.50
S39277	0.025	0.80	0.025	0.002	0.80	6.5–8.0	24.0–26.0	3.00–4.00	0.23–0.33	1.20–2.00	W 0.80–1.21

[A] Maximum, unless a range or minimum is indicated. Where ellipses (...) appear in this table, there is no minimum and analysis for the element need not be determined or reported.
[B] New designation established in accordance with Practice E 527 and SAE J1086.
[C] % Cr + 3.3 × % Mo + 16× % N.

7. Chemical Composition

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

8. Product Analysis

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

8.2 A product analysis tolerance (see the annex table on Chemical Requirements (Product Analysis Tolerances) in Specification A 480/A 480M) shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04 % or less.

8.3 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 this specification; otherwise, all remaining material in the heat shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets, lengths of flat-rolled stock, or tubes that do not meet the requirements of this specification shall be rejected.

NOTE 1—For flange and flaring requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness that 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 that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, or when heat treated condition is obtained directly by quenching after hot forming, 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 3.

NOTE 2—For tension and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that 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 that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, or when heat treated condition is obtained directly by quenching after hot forming, 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, or all tubes of the same size and heat, hot formed and quenched in the same production run.

9. Mechanical Tests Required

9.1 *Tension Tests*—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 (see Note 2).

9.2 *Flaring Test (for Seamless Tubes)*—One test shall be made on specimens from one end of one tube from each lot (see Note 1) of finished tubes. The minimum expansion of the inside diameter shall be 10 %.

9.3 *Flange Test (for Welded Tubes)*—One test shall be made on specimens from one end of one tube from each lot (see Note 1) of finished tubes.

9.4 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (see Note 2).

9.5 When more than one heat is involved, the tension, flaring, flanging, and hardness test requirements shall apply to each heat.

9.6 *Reverse Flattening Test*—For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

10. Hydrostatic or Nondestructive Electric Test

10.1 Each tube 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.

TABLE 2 Heat Treatment

UNS Designation	Temperature °F [°C]	Quench
S31200	1920–2010 [1050–1100]	rapid cooling in water
S31260	1870–2010 [1020–1100]	rapid cooling in air or water
S31500	1800–1900 [980–1040]	rapid cooling in air or water
S31803	1870–2010 [1020–1100]	rapid cooling in air or water
S32001	1800–1950 [982–1066]	rapid cooling in air or water
S32003	1850–2050 [1010–1120]	rapid cooling in air or water
S32101	1870 [1020] min	quenched in water or rapidly cooled by other means
S32205	1870–2010 [1020–1100]	rapid cooling in air or water
S32304	1700–1920 [925–1050]	rapid cooling in air or water
S32520	1975–2050 [1080–1120]	rapid cooling in air or water
S32550	1900 [1040] min	rapid cooling in air or water
S32707	1975–2050 [1080–1120]	rapid cooling in air or water
S32750	1880–2060 [1025–1125]	rapid cooling in air or water
S32760	2010–2085 [1100–1140]	rapid cooling in air or water
S32808	1920–2100 [1050–1150]	rapid cooling in air or water
S32900	1700–1750 [925–955]	rapid cooling in air or water
S32906	1870–2100 [1020–1150]	rapid cooling in air or water
S32950	1820–1880 [990–1025]	air cool
S39274	1920–2060 [1025–1125]	rapid cooling in air or water
S39277	1975–2155 [1080–1180]	rapid cooling in air or water

TABLE 3 Number of Tubes in a Lot Heat Treated by the Continuous Process or by Direct Quench after Hot Forming

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
Less than 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 wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

10.2 The hydrostatic test shall be in accordance with Specification A 1016/A 1016M, except that in the calculation of the hydrostatic test pressure *64000(441.2)* shall be substituted for *32000(220.6)*.

TABLE 4 Tensile and Hardness Requirements[A]

UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Hardness, max HBW	Hardness, max HRC
S31200	100 [690]	65 [450]	25	280	. . .
S31260[B]	100 [690]	65 [450]	25	290	30
S31500	92 [630]	64 [440]	30	290	30
S31803	90 [620]	65 [450]	25	290	30
S32001	90 [620]	65 [450]	25	290	30
S32003[C]	100 [690]	70 [485]	25	290	30
S32101					
Wall ≤ 0.187 in. [5.00 mm]	101 [700]	77 [530]	30	290	. . .
Wall > 0.187 in. [5.00 mm]	94 [650]	65 [450]	30	290	. . .
S32205	95 [655]	70 [485]	25	290	30
S32304					
OD 1 in. [25 mm] and Under	100 [690]	65 [450]	25	. . .	. . .
OD over 1 in. [25 mm]	87 [600]	58 [400]	25	290	30
S32520	112 [770]	80 [550]	25	310	. . .
S32550	110 [760]	80 [550]	15	297	31
S32707	133 [920]	101 [700]	25	318	34
S32750	116 [800]	80 [550]	15	300	32
S32760	109 [750]	80 [550]	25	300	. . .
S32808	116 [800]	80 [550]	15	310	32
S32900	90 [620]	70 [485]	20	271	28
S32906					
Wall below 0.40 in. (10 mm)	116 [800]	94 [650]	25	300	32
Wall 0.40 in. (10 mm) and above	109 [750]	80 [550]	25	300	32
S32950[D]	100 [690]	70 [480]	20	290	30
S39274	116 [800]	80 [550]	15	310	. . .
S39277	120 [825]	90 [620]	25	290	30

[A] For tubing smaller than ½ in. [12.7 mm] in outside diameter, the elongation values given for strip specimens in Table 4 shall apply. Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in outside diameter or with walls thinner than 0.015 in. [0.4 mm].
[B] Prior to A 789/A 789M–87, the values for S31260 were 92 ksi tensile strength, 54 ksi yield strength, and 30 % elongation.
[C] Prior to A 789/A 789M–04, the values for S32003 were 90 ksi tensile strength and 65 ksi yield strength.
[D] Prior to A 789/A 789M–89, the tensile strength value was 90 ksi for UNS S32950.

11. Tensile and Hardness Properties

11.1 The material shall conform to the tensile and hardness properties prescribed in Table 4.

12. Permissible Variations in Dimensions

12.1 Variations in outside diameter, wall thickness, and length from those specified shall not exceed the amounts prescribed in Table 5.

12.2 The permissible variations in outside diameter given in Table 5 are not sufficient to provide for ovality in thin-walled tubes, as defined in the table. In such tubes, the maximum and minimum diameters at any cross section shall deviate from the

TABLE 5 Permissible Variations in Dimensions

Group	Size, Outside Diameter, in. [mm]	Permissible Variations in Outside Diameter, in. [mm]	Permissible Variations in Wall Thickness,[A] %	Permissible Variations in Cut Length, in.[B] [mm]		Thin Walled Tubes[C]
				Over	Under	
1	Up to ½ [12.7], excl	±0.005 [0.13]	±15	⅛ [3]	0	. . .
2	½ to 1½ [12.7 to 38.1], excl	±0.005 [0.13]	±10	⅛ [3]	0	less than 0.065 in. [1.6 mm] nominal
3	1½ to 3½ [38.1 to 88.9], excl	±0.010 [0.25]	±10	3⁄16 [5]	0	less than 0.095 in. [2.4 mm] nominal
4	3½ to 5½ [88.9 to 139.7], excl	±0.015 [0.38]	±10	3⁄16 [5]	0	less than 0.150 in. [3.8 mm] nominal
5	5½ to 8 [139.7 to 203.2], incl	±0.030 [0.76]	±10	3⁄16 [5]	0	less than 0.150 in. [3.8 mm] nominal

[A] When tubes as ordered require wall thicknesses ¾ in. [19 mm] or over, or an inside diameter 60 % or less of the outside diameter, a wider variation in wall thickness is required. On such sizes a variation in wall thickness of 12.5 % over or under will be permitted.

For tubes less than ½ in. [12.7 mm] in inside diameter that cannot be successfully drawn over a mandrel, the wall thickness may vary ±15 % from that specified.

[B] These tolerances apply to cut lengths up to and including 24 ft [7.3 m]. For lengths greater than 24 ft [7.3 m], the above over-tolerances shall be increased by ⅛ in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft or ½ in. [13 mm], whichever is the lesser.

[C] Ovality provisions of 12.2 apply.

nominal diameter by no more than twice the permissible variation in outside diameter given in Table 5; however, the mean diameter at that cross section must still be within the given permissible variation.

13. Surface Condition

13.1 All tubes shall be free of excessive mill scale, suitable for inspection. A slight amount of oxidation will not be considered as scale. Any special finish requirements shall be subject to agreement between the manufacturer and the purchaser.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 1016/A 1016M, the marking shall indicate whether the tubing is seamless or welded.

15. Keywords

15.1 duplex stainless steel; ferritic/austenitic stainless steel; seamless steel tube; stainless steel tube; steel tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

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

S1. Air-Underwater Pressure Test

S1.1 When specified, each tube shall be examined by the air underwater pressure test.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 789/A 789M-05a, that may impact the use of this specification. (Approved September 1, 2005)

(*1*) Revised tensile properties for UNS S32003 in Table 4.
(*2*) Revised the Si content in Table 1 for UNS 32906 from 0.50 % to 0.80 %.
(*3*) Changed the annealing temperature in Table 2 for UNS 32906 to 1870–2100 °F [1020–1150 °C].
(*4*) Added Austenitic-Ferritic Grade UNS 32707 to Table 1, Table 2, and Table 4.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 789/A 789M-05, that may impact the use of this specification. (Approved June 1, 2005)

(*1*) Added new grade UNS S32808 to Table 1, Table 2, and Table 4.
(*2*) Editorially revised Table 1, Table 2, and Table 4.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 789/A 789M-04a, that may impact the use of this specification. (Approved March 1, 2005)

(*1*) Added stainless steel 32101 to Table 1, Table 2, and Table 4.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 789/A 789M-04, that may impact the use of this specification. (Approved July 1, 2004)

(*1*) Revised the quenching requirement for S31260 in Table 2.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 789/A 789M-02a, that may impact the use of this specification. (Approved March 1, 2004)

(*1*) Moved Note 1 from Scope to Footnote A in Table 4 and reordered the footnotes.

Designation: A 787 – 05

Standard Specification for Electric-Resistance-Welded Metallic-Coated Carbon Steel Mechanical Tubing[1]

This standard is issued under the fixed designation A 787; 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 covers round, square, rectangular, and special shape, electric-resistance-welded mechanical tubing, either zinc-coated (galvanized) after welding or produced from aluminum-coated, zinc-coated (galvanized), zinc-iron alloy-coated (galvannealed), or 55 % aluminum-zinc alloy-coated steel sheet. Tubing for use as electrical conduit (EMT) or intermediate metallic conduit (IMC) is not covered by this specification.

1.2 This specification covers mechanical tubing with outside diameters or maximum outside dimensions ranging from ½ to 8 in. (12.7 to 203.2 mm) and wall thickness from 0.028 to 0.134 in. (0.71 to 3.40 mm).

1.3 Sizes outside the ranges listed above may be ordered provided all other requirements of the specification are met.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 463/A 463M Specification for Steel Sheet, Aluminum-Coated by the Hot-Dip Process

A 653/A 653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

A 792/A 792M Specification for Steel Sheet, 55 % Aluminum-Zinc Alloy-Coated by the Hot-Dip Process

A 924/A 924M Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process

B 6 Specification for Zinc

3. Classification

3.1 The types of tubing covered by this specification are:

Type Number	Code Letters	Description
1	AWAC	electric-resistance-welded aluminum-coated carbon steel mechanical tubing
2	AWG	electric-resistance-welded galvanized carbon steel mechanical tubing
3	AWPG	electric-resistance-welded carbon steel mechanical tubing, post-hot dipped galvanized
4	AWGA	electric-resistance-welded carbon steel mechanical tubing, zinc-iron alloy-coated (galvannealed)
5	AWGZ	electric-resistance-welded carbon steel mechanical tubing, 55 % aluminum-zinc alloy-coated

4. Ordering Information

4.1 The ordered wall thickness of the tubing shall be the total of the base metal and the metallic coating.

4.2 Orders for material under this specification shall include the following:

4.2.1 Quantity (feet, metres, or number of lengths),

4.2.2 Type, code letters, and description (Sections 1 and 3),

4.2.3 Applicable ASTM designation number(s),

4.2.4 Coating designation and type of coating,

4.2.5 Chemically treated or not chemically treated raw material,

4.2.6 Oiled or dry (Section 16),

4.2.7 Extra smooth coating (if required),

4.2.8 Customer application, including fabrication,

4.2.9 Flash condition (7.1),

4.2.10 Steel grade designation (Sections 5 and 9),

4.2.11 Report of chemical analysis if required (Sections 10 and 11),

4.2.12 Shape (round, square, rectangular, or special),

4.2.12.1 Dimensions: round—any two of the following: inside diameter, outside diameter, or wall thickness; square or rectangular—outside dimension, wall thickness, and corner radii, if required. (See 12.1 and 13.1 and 13.2.)

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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 A01.09 on Carbon Steel Tubular Products.

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[2] 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.

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

4.2.13 Length: round tubing—mill lengths or definite cut lengths (see 12.2); square and rectangular tubing—mill cut lengths and specified length (see 13.4).
4.2.14 Squareness of cut: round tubing, if required (see 12.3); square and rectangular tubing, if required (see 13.7),
4.2.15 Burrs removed, if required (see 15.2),
4.2.16 Special packaging (Section 19),
4.2.17 Customer specification number, if applicable,
4.2.18 Special requirements,
4.2.19 Special marking (Section 18), and
4.2.20 Recoating of outside diameter weld and heat-affected area, on precoated steel, if required.

5. Process

5.1 The steel shall be made from any process.
5.1.1 If a specific type of melting is required by the purchaser, it shall be stated on the purchase order.
5.1.2 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, using electroslag remelting or vacuum remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.
5.1.3 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.
5.2 For tubing produced from precoated steel sheet, the composition of the coating shall comply with the applicable specification.
5.2.1 *Specification A 463/A 463M*—Coating designation for aluminum coated-sheet.
5.2.2 *Specification A 653/A 653M*—Coating designation for galvanized and galvannealed steel sheet.
5.2.3 *Specification A 792/A 792M*—Coating designation for 55 % aluminum-zinc alloy-coated steel sheet.
5.2.4 Other grades of coated steel sheet, as listed in Table 1 and Table 2, may be used as the precoated material for the steel tubing upon agreement between the manufacturer and the purchaser. Such steel sheet shall meet the requirements of Specification A 463/A 463M, A 653/A 653M, A 792/A 792M, and A 924/A 924M, except for the chemical requirements.

TABLE 1 Chemical Requirements for Low-Carbon Steels[A,B]

Grade Designation[C]	Composition, %			
	Carbon	Manganese	Phosphorus, max	Sulfur, max
MT1010	0.05 to 0.15	0.30 to 0.60	0.035	0.035
MT1015	0.10 to 0.20	0.30 to 0.60	0.035	0.035
MTX1015	0.10 to 0.20	0.60 to 0.90	0.035	0.035
MT1020	0.15 to 0.25	0.30 to 0.60	0.035	0.035
MTX1020	0.15 to 0.25	0.70 to 1.00	0.035	0.035

[A] Rimmed or capped steels that may be used for the above grades are characterized by a lack of uniformity in their chemical composition, and for this reason product analysis is not technologically appropriate unless misapplication is clearly indicated.
[B] Chemistry represents heat analysis. Product analysis, except for rimmed or capped steel, is to be in accordance with usual practice as shown in Table 5.
[C] The letters MT indicate mechanical tubing.

TABLE 2 Chemical Requirements for Other Carbon Steels[A]

Grade Designation	Composition, %			
	Carbon	Manganese	Phosphorus, max	Sulfur, max
1008	0.10 max	0.50	0.035	0.035
1010	0.08 to 0.13	0.30 to 0.60	0.035	0.035
1015	0.12 to 0.18	0.30 to 0.60	0.035	0.035
1016	0.12 to 0.19	0.60 to 0.90	0.035	0.035
1017	0.14 to 0.21	0.30 to 0.60	0.035	0.035
1018	0.14 to 0.21	0.60 to 0.90	0.035	0.035
1019	0.14 to 0.21	0.70 to 1.00	0.035	0.035
1021	0.17 to 0.24	0.60 to 0.90	0.035	0.035

[A] Chemistry represents heat analysis. Product analysis, except for rimmed or capped steel, is to be in accordance with usual practice as shown in Table 5.

6. Manufacture

6.1 Tubes shall be made by the electric-resistance welding process and shall be made from hot or cold-rolled precoated steel.
6.2 Special manufacturing practices allow for post-hot dipped galvanizing of welded tubing. If this product is desired all sections of this specification will apply except Table 3. Wall thickness tolerances shall be determined by agreement between the producer and purchaser.

7. Flash Conditions

7.1 The flash conditions under which tubing may be furnished are as follows: The flash shall be removed from the outside diameter of tubing covered by this specification. Tubing furnished to this specification may have the following conditions of welding flash on the inside diameter.
7.1.1 *Flash-In*— All tubing in which the inside diameter welding flash does not exceed the wall thickness or 3⁄32 in. (2.4 mm), whichever is less.
7.1.2 *Flash Controlled to 0.010 in. (0.254 mm), Maximum*— Tubing in which the height of the remaining welding flash is controlled so as not to exceed 0.010 in. This condition is available in over 0.750 in. (19.05 mm) outside diameter and gages consistent with Table 4.
7.1.3 *Flash Controlled to 0.005 in. (0.127 mm), Maximum*—When the inside diameter flash is controlled to 0.005 in. (0.127 mm) maximum in tubing produced to outside diameter and wall thickness, inside diameter and wall thickness, or outside diameter and inside diameter tolerances, the remaining inside diameter flash, if any, is part of the applicable inside diameter tolerance. This controlled flash is available in 0.750 in. (19.05 mm) outside diameter or greater.
7.2 Tubes shall be furnished in the following shapes, as specified by the purchaser: round, square, rectangular, or special shapes (as negotiated).
7.3 Recoating of the outside diameter weld-heat-affected area on precoated steel tubing may be performed at the manufacture's option, if not specifically requested by the purchaser.

8. Surface Finish

8.1 Special surface finishes as may be required for specific applications shall be provided in the purchase order by agreement between the producer and purchaser.

TABLE 3 Wall Thickness Tolerance for Premetallic Coated As-Welded Tubing[A]
Outside Diameter, in.

Wall Thickness		½ to 1, incl		Over 1 to 1 15/16, incl		Over 1 15/16 to 3¾, incl		Over 3¾ to 4½, incl		Over 4½ to 6, incl		Over 6 to 8, incl	
		Wall Thickness Tolerance, in., Plus and Minus											
BWG[B]	in.[C]	Plus	Minus	Plus	Minus	Plus	Minus	Plus	Minus	Plus	Minus	Plus	Minus
22	0.028	0.002	0.006	0.002	0.006								
20	0.035	0.003	0.006	0.002	0.006	0.002	0.006						
18	0.049	0.004	0.007	0.003	0.008	0.003	0.008						
16	0.065	0.005	0.007	0.004	0.008	0.003	0.009	0.003	0.009	0.002	0.010		
14	0.083	0.006	0.008	0.006	0.008	0.005	0.009	0.005	0.009	0.004	0.010	0.004	0.010
13	0.095	0.008	0.010	0.008	0.010	0.007	0.011	0.007	0.011	0.006	0.012	0.006	0.012
12	0.109	0.008	0.010	0.008	0.010	0.007	0.011	0.007	0.011	0.006	0.012	0.006	0.012
11	0.120	0.009	0.011	0.009	0.011	0.008	0.012	0.008	0.012	0.007	0.013	0.007	0.013
10	0.134	0.009	0.011	0.009	0.011	0.008	0.012	0.008	0.012	0.007	0.013	0.007	0.013

[A] Post-hot dipped galvanized welded tubing wall thickness tolerances shall be determined by agreement between the producer and purchaser (6.2).
[B] Birmingham Wire Gage.
[C] 1 in. = 25.4 mm.

TABLE 4 Diameter Tolerances for Metallic-Coated
Round Tubing

Outside Diameter Range, in.[A]	Wall Thickness		Tubing with Any Inside Flash Condition	Flash-Controlled to 0.005 in. Tubing Only[B]
	BWG[C]	in.[A]	Outside[D,E] Diameter, Plus and Minus	Inside Diameter, Plus and Minus
			Tolerances, in.[F]	
½ to 1⅛, incl	22 to 16	0.028/0.065	0.0035	0.019
Over 1⅛ to 2, incl	22 to 14	0.028/0.083	0.005	0.021
Over 1⅛ to 2, incl	13 to 10	0.095/0.134	0.005	0.027
Over 2 to 2½, incl	20 to 14	0.035/0.083	0.006	0.023
Over 2 to 2½, incl	13 to 10	0.095/0.134	0.006	0.029
Over 2½ to 3, incl	20 to 14	0.035/0.083	0.008	0.025
Over 2½ to 3, incl	13 to 10	0.095/0.134	0.008	0.031
Over 3 to 3½, incl	20 to 14	0.035/0.083	0.009	0.026
Over 3 to 3½, incl	13 to 10	0.095/0.134	0.009	0.032
Over 3½ to 4, incl	20 to 14	0.035/0.083	0.010	0.027
Over 3½ to 4, incl	13 to 10	0.095/0.134	0.010	0.033
Over 4 to 5, incl	16 to 14	0.065/0.083	0.020	0.037
Over 4 to 5, incl	13 to 10	0.095/0.134	0.020	0.043
Over 5 to 6, incl	16 to 14	0.065/0.083	0.020	0.037
Over 5 to 6, incl	13 to 10	0.095/0.134	0.020	0.043
Over 6 to 8, incl	14 to 10	0.083/0.134	0.025	0.048

[A] 1 in. = 25.4 mm.
[B] Flash controlled to 0.005 in. maximum tubing is produced to outside diameter tolerances and wall thickness tolerances, inside diameter tolerances and wall thickness tolerances, or outside diameter tolerances and inside diameter tolerances, in which the height of the remaining inside welding flash is controlled not to exceed 0.005 in. Any remaining flash is considered to be part of the applicable inside diameter tolerances.
[C] Birmingham Wire Gage.
[D] Flash-in tubing is produced to outside diameter tolerances and wall thickness tolerances only, and the height of the inside welding flash does not exceed the wall thickness or 3/32 in., whichever is less.
[E] Flash controlled to 0.010 in maximum tubing consists of tubing over 5/8 in. outside diameter which is commonly produced to outside diameter tolerances and wall thickness tolerances only, in which the height of the remaining inside welding flash is controlled not to exceed 0.010 in.
[F] The ovality shall be within the above tolerances except when the wall thickness is less than 3 % of the outside diameter, in which cases see 12.5.

9. Base Metal Chemical Composition

9.1 The chemical composition of the sheet steel base metal shall conform to the requirements of Table 1.

9.2 Copper-bearing steel, with 0.20 % minimum copper, may be ordered in any of the grades shown in Table 1 or Table 2.

9.3 An analysis of each heat of steel shall be made by the basic steel producer to determine the percentage of the elements specified. The heat analysis, as supplied by the steel melter, shall conform to the requirements of Table 1 or Table 2.

9.4 When a grade is 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 and Table 2 is not permitted.

10. Coating Bath Chemical Composition

10.1 When tubing is produced from precoated sheet steel, the tubing manufacturer shall furnish, upon request, a report stating that the tubing has been manufactured from precoated sheet steel meeting one of the following specifications: A 463/A 463M, A 653/A 653M, A 792/A 792M, and A 924/A 924M.

10.2 For post-coated tubing the zinc used for coating shall be any grade of zinc conforming to Specification B 6.

11. Product Analysis

11.1 When requested on the purchase order, a product analysis shall be made by the supplier. The number and source of samples for a product analysis shall be based on the individual heat or lot identity of one of the following forms:

11.1.1 *Heat Identity Maintained*—One product analysis per heat shall be made on either the flat-rolled stock or tube.

11.1.2 *Heat Identity Not Maintained*—One product analysis shall be made from each 2000 ft (610 m) or fraction thereof for sizes over 3 in. (76.2 mm) outside diameter, and from each 5000 ft (1524 m) or fraction thereof for sizes 3 in. (76.2 mm) outside diameter and under.

11.2 Samples for product spectrochemical analysis shall be taken in accordance with procedures established with the tube producer and the testing laboratory. The composition thus determined shall correspond to the requirements in Table 1 or Table 2 and be within the composition tolerances shown in Table 5.

11.3 If the original test for product analysis fails, retests of two additional samples of flat-rolled stock or tubes shall be made. Both retests for the elements in question shall meet the requirements of Table 1 or Table 2, and Table 5, of this specification; otherwise, all remaining material in the heat or lot shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Any retested material not meeting the requirements of this specification shall be rejected.

12. Permissible Variations in Dimensions for Round Tubing

12.1 *Wall Thickness and Diameter*—Wall thickness tolerances for tubing made from precoated steel are shown in Table 3. All wall thickness tolerances include both the base steel and the coating (inside and outside surfaces). Variations in outside diameter and inside diameter of as-welded tubing made from precoated steel are shown in Table 4.

12.2 *Length*—Mechanical tubing is commonly furnished in mill lengths 5 ft (1.5 m) and over. Mill length tolerances are given in Table 6. Definite cut lengths are furnished when specified by the purchaser. Tolerances for definite length round tubing shall be given in Table 7 and Table 8. Different types of cutting methods will affect the end cut.

12.3 *Squareness of Cut*—When specified, the tolerance for squareness of cut of round mechanical tubing is shown in Table 9. Measurements are made with the use of an "L" square and feeler gage. The contact length of the side leg of the square along the tube will be equal to or greater than the tube outside diameter, but not less than 1 in. (25.4 mm) nor greater than 4 in. (101.6 mm). The other leg shall always be equal to or greater than the tube outside diameter.

12.4 *Straightness*:

12.4.1 *Post-Coated Tubing*—The straightness tolerance for round mechanical tubing shall be 0.030 in. (0.762 mm) maximum in any 3-ft (0.914-m) length of tubing. The straightness tolerance on shorter lengths and on special requirements shall be agreed upon between the purchaser and producer.

12.4.2 *Precoated Tubing*—The straightness requirement for post-coated tubing shall be by agreement between the purchaser and producer.

12.5 *Ovality*—The ovality shall be within the tolerances of Table 4 except when the wall thickness is less than 3 % of the outside diameter. When the tube wall thickness is less than 3 % of the tube outside diameter the ovality may be 50 % greater than the outside diameter tolerances, but the mean diameter (average of maximum outside diameter and minimum outside diameter) shall be within the specified tolerance.

13. Permissible Variations in Dimensions of Square and Rectangular Tubing

13.1 *Diameter and Wall Thickness*—Permissible variations in outside dimensions for square and rectangular tubing are shown in Table 10. The wall thickness tolerance is ±10 % of the nominal wall thickness and is measured at the center width of the unwelded sides.

TABLE 5 Tolerances for Product Analysis for Steels Shown in Table 1[A]

Element	Limit or Maximum of Specified Range, %	Variation, Over the Maximum Limit or Under the Minimum Limit	
		Under min, %	Over max, %
Carbon	to 0.15, incl	0.02	0.03
	over 0.15 to 0.40, incl	0.03	0.04
	over 0.40 to 0.55, incl	0.03	0.05
Manganese	to 0.60, incl	0.03	0.03
	over 0.60 to 1.00 incl	0.04	0.04
Phosphorus	. . .	. . .	0.01
Sulfur	. . .	. . .	0.01
Copper	. . .	0.02	. . .

[A] Individual determinations may vary from the specified heat limits or ranges to the extent shown in this table, except that any element in a heat may not vary both above and below a specified range.

TABLE 6 Mill Cut-Length Tolerances for Round, Square, and Rectangular Tubing

Outside Diameter Size, in.[A]	5 ft to Under 24 ft	24 ft and Over[B]
½ to 8, incl	+1.0, −0.0 in.	+4.0, −0.0 in.

[A] 1 in. = 25.4 mm.
[B] Manufacturing practices may limit the length available; therefore, when inquiring, it is essential to describe the product fully.

TABLE 7 Cut Length Tolerances for Lathe-Cut Round Tubing

Outside Diameter Size, in.[A]	6 in. and Under 12 in.	12 in. and Under 48 in.	48 in. and Under 10 ft	10 ft to 24 ft, incl[B]
3/8 to 3, incl	±1/64	±1/32	±3/64	±1/8
Over 3 to 6, incl	±1/32	±3/64	±1/16	±1/8
Over 6 to 8, incl	±1/16	±1/16	±1/8	±1/8

[A] 1 in. = 25.4 mm.
[B] For each additional 10 ft or fraction thereof over 24 ft, an additional allowance should be made of ±1/16 in.

TABLE 8 Cut-Length Tolerances for Tubing Punch-, Saw-, or Disc-Cut Round Tubing

Outside Diameter Size, in.[A]	6 in. and under 12 in.	12 in. and under 48 in.	48 in. and under 10 ft.	10 ft. and 24 ft. incl
1/8 to 3 incl.	±1/16 in.	±1/16 in.	±1/8 in.	±1/4 in.
Over 3 to 6, incl.	±1/16 in.	±1/16 in.	±1/8 in.	±1/4 in.
Over 6 to 8, incl.	±1/16 in.	±1/16 in.	±1/8 in.	±1/4 in.

[A] 1 in. = 25.4 mm

TABLE 9 Tolerance for Squareness of Cut (Either End) When Specified for Round Tubing[A,B]

Length of Tube, ft[C]	Outside Diameter, in.[B,D]				
	Under 1	1 to 2, incl	Over 2 to 3, incl	Over 3 to 4, incl	Over 4
Under 1	0.006	0.008	0.010	0.015	0.020
1 to 3, incl	0.008	0.010	0.015	0.020	0.030
Over 3 to 6, incl	0.010	0.015	0.020	0.025	0.040
Over 6 to 8, incl	0.015	0.020	0.025	0.030	0.040

[A] Actual squareness normal to length of tube, not parallelness of both ends.
[B] Values given are "go" value of feeler gage. "No-go" value is 0.001 in. greater in each case.
[C] 1 ft = 0.3 m.
[D] 1 in. = 25.4 mm.

13.2 *Corner Radii*—Unless otherwise specified the inside and outside corners of square and rectangular tubing shall be slightly rounded, consistent with the tube wall thickness. A slight radius flattening can be expected and is more pronounced with heavier-walled tubing. However, the radii of the corners shall be in accordance with Table 11.

13.3 *Squareness of Sides*—Permissible variation of squareness of sides shall be determined by the following equation:

$$\pm b = c \times 0.006 \text{ in.}$$

where:
b = tolerance for out-of-square, and
c = largest external dimension across flats.

The squareness of sides is commonly determined by one of the following methods:

13.3.1 A square with two adjustable contact points on each arm is placed on two sides. A fixed feeler gage is then used to measure the maximum distance between the free contact point and the surface of the tubing.

13.3.2 A square equipped with a direct-reading vernier may be used to determine the angular deviation that, in turn, may be related to distance in inches.

13.4 *Length*—Tolerances for mill cut-length square and rectangular tubing shall not exceed the amounts shown in Table 4. Tolerances for definite length square and rectangular tubing shall not exceed the amount shown in Table 12.

TABLE 10 Tolerances, Outside Dimensions[A] Square and Rectangular Tubing

Largest Nominal Outside Dimension, in.[B]	Wall Thickness, in.[B]	Outside Tolerance at All Sides at Corners, ± in.[B]
3/16 to 5/8 , incl	0.020 to 0.083, incl	0.004
Over 5/8 to 1 1/8 , incl	0.025 to 0.134, incl	0.005
Over 1 1/8 to 1 1/2 , incl	0.025 to 0.134, incl	0.006
Over 1 1/2 to 2, incl	0.032 to 0.134, incl	0.008
Over 2 to 3, incl	0.035 to 0.134, incl	0.010
Over 3 to 4, incl	0.049 to 0.134, incl	0.020
Over 4 to 6, incl	0.065 to 0.134, incl	0.020
Over 6 to 8, incl	0.085 to 0.134, incl	0.025

Convexity and concavity: Tubes having two parallel sides are also measured in the center of the flat sides for convexity and concavity. This tolerance applies to the specific size determined at the corners, and is measured on the following basis:

Largest Nominal Outside Dimension, in.	Tolerance, Plus and Minus, in.
2 1/2 and under	0.010
Over 2 1/2 to 4	0.015
Over 4 to 8	0.025

[A] Measured at corners at least 2 in. from the cut end of the tubing.
[B] 1 in. = 25.4 mm.

TABLE 11 Radii of Corners of Electric-Resistance Welded Square and Rectangular Tubing[A]

Squares and Rectangles Made from Tubes of the Following Diameter Ranges, in.[B]	Wall Thickness, BWG (in.)[B]	Radius Ranges, in.[C]
1/2 to 1 1/2 , incl	22 (0.028)	1/32 to 1/16
1/2 to 2 1/2 , incl	20 (0.035)	1/32 to 1/16
1/2 to 4, incl	18 (0.049)	3/64 to 5/64
1/2 to 4 1/8 , incl	16 (0.065)	1/16 to 7/64
3/4 to 4 1/8 , incl	14 (0.083)	5/64 to 1/8
Over 4 1/8 to 6, incl	14 (0.083)	3/16 to 5/16
1 to 4 1/8 , incl	13 (0.095)	3/32 to 5/32
Over 4 1/8 to 6, incl	13 (0.095)	3/16 to 5/16
1 1/4 to 4, incl	12 (0.109)	1/8 to 13/64
Over 4 to 6, incl	12 (0.109)	3/16 to 5/16
1 1/4 to 4, incl	11 (0.120)	1/8 to 7/32
Over 4 to 6, incl	11 (0.120)	7/32 to 7/16
2 to 4, incl	10 (0.134)	5/32 to 9/32
Over 4 to 6, incl	10 (0.134)	7/32 to 7/16
Over 6 to 8, incl	10 (0.134)	3/8 to 5/8

[A] This table establishes a standard radius. The purchaser and producer may negotiate special radii. Slight radius flattening is more pronounced in heavier wall tubing.
[B] 1 in. = 25 mm.
[C] These radius tolerances apply to grades of steel covered in Table 1. The purchaser and producer may negotiate tolerances on other grades of steel.

TABLE 12 Length Tolerances for Definite Length Square and Rectangular Tubing

Lengths, ft[A]	Tolerances, in.[B]
1 to 3, incl	±1/16
Over 3 to 12, incl	±3/32
Over 12 to 20, incl	±1/8
Over 20 to 30, incl	±3/16
Over 30 to 40, incl	±1/4

[A] 1 ft = 0.3 m.
[B] 1 in. = 25.4 mm.

13.5 *Twist*—Twist tolerances are shown in Table 13. The twist in square and rectangular tubing may be measured by holding one end of the tubing on a surface plate and noting the height of either corner of the opposite end of the same side

TABLE 13 Twist Tolerances Electric-Resistance-Welded for Square and Rectangular Mechanical Tubing

Largest Dimension, in.[A]	Twist Tolerance in 3 ft,[B] in.[A]
Under ½	0.032
Over ½ to 1½ , incl	0.050
Over 1½ to 2½ , incl	0.062
Over 2½ to 4, incl	0.075
Over 4 to 6, incl	0.087
Over 6 to 8, incl	0.100

[A] 1 in. = 25.4 mm.
[B] 1 ft = 0.3 m.

above the surface plate. Twist may also be measured by the use of a beveled protractor equipped with a level, and noting the angular deviation on opposite ends, or at any point throughout the length.

13.6 *Straightness*—The straightness tolerance is 1⁄16 in. in 3-ft length (1.7 mm/m).

13.7 *Squareness of Cut*—If required, the squareness of cut for square and rectangular tubing shall be equal to or less than 0.050 in. (1.27 mm). Measurements are made with an "L" square and feeler gage. The contact length of the side leg of the square along the tube will be equal to or greater than the largest outside dimension of the tube but shall never be less than 1 in. (25.4 mm) nor greater than 4 in. (101.6 mm). The other leg will always be equal to or greater than the largest outside dimension of the tube.

14. Tubing Sections Other Than Square and Rectangular

14.1 In addition to square and rectangular tubing, many producers supply a wide variety of special sections. However, manufacturing practices limit the size range and sections that are available from the various producers. Since the sections are special, they must be inquired on an individual basis giving full details as to dimensions and finish.

15. Workmanship, Finish, and Appearance

15.1 The tubing shall have a workmanlike finish.

15.2 When burrs must be removed from one or both ends, it shall be specified in the purchase order.

16. Oiling

16.1 When specified, tubing shall have a protective coating applied before shipping to retard white rust of the metallic coating on closely nested products and red rust on non-recoated outside diameter weld areas. Should the order specify shipment without a protective coating, the lubricant incidental to manufacturing will remain and the purchaser will assume responsibility for rust in transit and storage.

17. Rejection

17.1 Tubes that fail to meet the requirements of this specification shall be set aside and the producer shall be notified.

18. Product Marking

18.1 Each box, bundle, lift, or piece shall be identified by a tag or stencil with the manufacture's name or brand, specified size, type, purchaser's order number, and this specification number.

18.2 *Bar Coding*—In addition to the requirements in 18.1 bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

19. Packaging

19.1 On tubing 16 gage (1.65 mm nominal) and lighter, the producer will determine whether or not the tubing will be boxed, crated, cartoned, packaged in secured lifts, or bundled to ensure safe delivery unless otherwise instructed. Tubing heavier than 16 gage will normally be shipped loose, bundled, or in secured lifts. Special packaging requiring extra operations other than those normally used by a producer must be specified on the order.

20. Keywords

20.1 carbon steel tube; metallic-coated tubing; resistance welded steel tube; steel tube; welded steel tube

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 787 – 01, that may impact the use of this specification. (Approved March 1, 2005)

(*1*) Revised Table 4.

Designation: A 778 – 01

Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products[1]

1. Scope

1.1 This specification covers straight seam and spiral butt seam welded unannealed austenitic stainless steel tubular products intended for low and moderate temperatures and corrosive service where heat treatment is not necessary for corrosion resistance. Table 1 lists the five grades covered by this specification. The user of this specification should be aware that a minimum amount of testing and examination is required of the basic product. The user requiring additional testing or examination is referred to the supplemental requirements or Ordering Information, or both. Users requiring a tubular product with post-weld heat treatment or with radiographic examination are referred to Specification A 312/A 312M, A 358/A 358M, or A 409/A 409M, as applicable.

1.2 This specification covers welded unannealed tubular products 3 in. (75 mm) through 48 in. (1200 mm) in outside diameter and in nominal wall thicknesses of 0.062 in. (1.5 mm) through 0.500 in. (12.5 mm) produced to this specification. Tubular products having other diameters or wall thickness, or both, may be furnished provided it complies with all other requirements of this specification.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 240 Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels[2]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels[2]

A 312/A 312M Specification for Seamless and Welded Austenitic Stainless Steel Pipes[3]

A 358/A 358M Specification for Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High-Temperature Service[3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 409/A 409M Specification for Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service[3]

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment[4]

A 941 Terminology Relating to Steel, Related Alloys, and Ferroalloys[3]

A 999/A 999M Specification for General Requirements for Alloy and Stainless Steel Pipe[3]

E 340 Test Method for Macroetching Metals and Alloys[5]

E 527 Practice for Numbering Metals and Alloys (UNS)[3]

2.2 *AWS Standards:*

A 5.4 Corrosion—Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes[6]

A 5.9 Corrosion–Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes[6]

2.3 *SAE Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[7]

3. Terminology

3.1 *Definitions:*

3.2 The definitions in Specification A 999/A 999M and Terminology A 941 are applicable to this specification.

4. Ordering Information

4.1 Orders for material to this specification should include the following:

4.1.1 Quantity (feet, metres, or number of pieces),

4.1.2 Name of material (welded unannealed austenitic stainless steel tubular products),

4.1.3 Straight seam or spiral butt seam,

4.1.4 Grade (see Table 1),

4.1.5 Size (outside diameter and specified wall thickness) (see 10.3 and 10.4),

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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.

Current edition approved Mar. 10, 2001. Published June 2001. Originally published as A 778 – 80. Last previous edition A 778 – 00.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

[4] *Annual Book of ASTM Standards*, Vol 01.05.

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

[6] Available from American Welding Society, 2501 N.W. 7th St., Miami, FL 33125.

[7] Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

TABLE 1 Chemical Requirements

Grade	UNS Designation[A]	Carbon max[B]	Manganese, max	Phosphorus, max	Composition, %					Titanium	Columbium Plus Tantalus	Nitrogen, max
					Sulfur, max	Silicon, max	Chromium	Nickel				
TP 304L	S30403	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–13.0	...	...	...	0.10
TP 316L	S31603	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00 3.00	...	...	0.10
TP 317L	S31703	0.030	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0 4.0	...	...	0.10
TP 321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	[C]	...	...
TP 347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	[D]	...

[A] New designation established in accordance with Practice E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).
[B] The carbon analysis shall be reported to the nearest 0.01 %, except for the low carbon (0.030) types, which shall be reported to the nearest 0.001 %.
[C] The titanium content shall be not less than five times the carbon content and not more than 0.70 %.
[D] The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.10 %.

4.1.6 Length (mill standard lengths, or specify cut lengths) (see 10.1),

4.1.7 Optional requirements (Supplementary Requirements S1 to S5),

4.1.8 Certification requirements,

4.1.9 Specification designation, and

4.1.10 Special requirements.

5. Significance and Use

5.1 It is anticipated that the ASTM Subcommittees A01.06, A01.10, A01.17, A01.22, and A01.28 will use the standard composition limits listed in this specification for the grades identified by the corresponding UNS designation in the product specification unless there is a specific technical justification for doing otherwise. The compositions in this specification shall not be considered as chemical requirements for any particular product until adopted by the subcommittee overseeing that product.

6. Manufacture

6.1 The tubular products shall be made from flat-rolled steel sheet, coil, or plate by a shielded arc-welding process. The material used for manufacture shall conform to the requirements of one of the grades of Specification A 240 listed in Table 1. At the manufacturer's option, filler metal may be used.

6.2 Tubular products 14 in. (350 mm) in diameter and smaller shall have a single longitudinal weld or a spiral butt weld seam. Tubular products of larger diameter may have a maximum of three longitudinal welds. All weld tests, examinations, inspections, or treatments are to be performed on each weld seam.

6.3 Circumferentially welded joints of the same quality as the longitudinal or spiral joints shall be permitted by agreement between the manufacturer and the purchaser.

6.4 All tubular products shall be furnished clean and free of scale.

6.5 *Welding*:

6.5.1 The welds shall be made by the manual or automatic electric-welding process.

6.5.2 The welded joints may show a reinforcing bead no greater than $\frac{1}{16}$ in. (1.6 mm) on either surface of the tubular product. At no place shall the thickness of the weld section be less than the minimum wall thickness permitted by the tolerances of 10.4. The weld bead may be removed at the option of the manufacturer or upon agreement between the manufacturer and purchaser.

6.5.3 Injurious weld defects shall be repaired by removal to sound metal and rewelding.

6.5.4 The alloy content (chromium, nickel, molybdenum, columbium, and carbon) of the filler metal shall conform to that required for the plate or the welding electrodes as shown in Table II of Specification AWS A5.4 or in Table I of Specification AWS A5.9, except that when welding on Type 321 base metal, the deposited weld metal may correspond to Type 347.

7. Mechanical Test Requirements

7.1 Each lot shall be subjected to one transverse tension test and two transverse guided bend tests.

NOTE 1—The term *lot* applies to all pipe of the same grade, of the same thickness, produced from the same heat with the same weld procedure.

7.2 The maximum lot size shall be in accordance with the following table:

Diameter Range	Lot Size (lengths)
up to 3 in. exclusive	400
3–8 in. exclusive	300
8–14 in. exclusive	200
14 in. and over	100

7.3 *Specimen Preparation*:

7.3.1 Transverse tension and bend test specimens shall be taken from the end of a length and shall be flattened cold before final machining to size.

7.3.2 As an alternative to the requirements of 7.3.1, the test specimens may be taken from test plates of the same material as the tube, which are attached to the end of the cylinder and welded as a prolongation of the tube longitudinal weld.

7.3.3 Tension test specimens shall be made in accordance with Test Methods and Definitions A 370.

7.4 *Transverse Tension Test*:

7.4.1 Transverse tension tests taken transversely across the welded joint shall meet the same minimum tensile strength as the base material (Table 2).

7.4.2 When diameters below 8-in. (200 mm) make it impractical to perform a transverse tension test, an alternative test may be permitted by agreement between the manufacturer and the purchaser.

7.5 *Transverse Guided—Bend Weld Test*:

TABLE 2 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min, ksi (MPa)
TP 304L	S30403	70 (485)
TP 316L	S31603	70 (485)
TP 317L	S31703	75 (515)
TP 321	S32100	75 (515)
TP 347	S34700	75 (515)

7.5.1 Take two bend test specimens transversely from the weld. Subject one to a face guided-bend test and the second to a root guided-bend test. Bend one specimen with the inside surface of the tube against the plunger, and the other with the outside surface against the plunger.

7.5.2 The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. (3 mm) in any direction are present in the weld metal or between the weld and the parent metal after bending. Cracks that originate along the edges of the specimen during testing, and that are less than ¼ in. (6 mm) measured in any direction shall not be considered.

7.5.3 Make and test transverse guided-bend weld test specimens in accordance with Test Methods and Definitions A 370.

7.5.4 When diameters below 8 in. (200 mm) make it impractical to perform a transverse guided-bend test, a flattening test may be substituted (see Supplementary Requirement S5).

8. Heat Treatment

8.1 Heat treatment shall not be required.

9. Chemical Requirements

9.1 Mill certificates of heat analysis of each heat of steel shall be furnished upon request.

10. Permissible Variations in Tubular Products Dimensions

10.1 *Lengths*—Tubular products are normally furnished in mill lengths 10 ft (3 m) and over. If specific lengths are ordered, no length shall be under the length specified and not more than ¼ in. (6 mm) over that specified.

10.2 *Straightness*—Using a 10-ft (3-m) straightedge placed so that both ends are in contact with the length, a maximum of a 0.25-in. (6-mm) gap is allowable.

10.3 *Diameter Tolerance*—Refer to the applicable table in Specification A 999/A 999M.

10.4 *Wall Thickness*—Wall thickness tolerance shall be ±12.5 %.

11. Workmanship

11.1 Finished products shall have smooth ends free of burrs. Tubular products shall be free of injurious defects and shall have a workmanlike finish. Surface imperfections, such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale patterns, will not be considered as serious defects, provided the imperfections are removable within the allowable wall thickness tolerance. The removal of surface imperfections is not required.

12. Inspection

12.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

13. Rejection

13.1 Each length of tube received from the manufacturer may be inspected by the purchaser. If it does not meet the requirements of this specification based on the inspection and test method as outlined, the length may be rejected and the manufacturer shall be notified. Disposition of rejected lengths shall be a matter of agreement between the manufacturer and the purchaser.

14. Certification

14.1 A certification that the material conforms to the requirements of this specification shall be the basis of acceptance of the material. When requested by the purchaser, the manufacturer shall report to the purchaser or his representative the results of any supplemental test requirements.

15. Product Marking

15.1 Each length of tube shall be legibly marked with the manufacturer's name or brand, specified size, heat number, this specification number, grade of material, and the letters *HT-O* to indicate that the pipe was not heat treated.

15.2 For small-diameter tubes and pieces under 3 ft (0.90 m) in length, the information specified in 15.1 shall be marked on a tag securely attached to the bundle or box in which the pieces are shipped.

16. Packaging

16.1 Tubular products may be shipped loose. The manufacturer may, at his option, box, crate, or package in secure lifts or bundles to ensure safe delivery as specified in Practices A 700.

17. Keywords

17.1 austenitic stainless steel; stainless steel tubing; steel tubing; welded steel tubing

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements may be included in the purchaser's inquiry or in the order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Details of a supplementary requirement shall be agreed to between the manufacturer and the purchaser.

S1. Etching Tests

S1.1 An etching test, when specified, shall be made on a transverse section from one end of one length from each 2500 ft (760 m) or fraction thereof from each heat of steel or as specified by the purchaser. An etching test in accordance with Test Method E 340 shall be made. The test shall show sound, homogeneous, and reasonable uniform material, free of injurious laminations, cracks, and similar objectionable defects. If the specimen of any length shows objectional defects, one retest shall be permitted from the same end. If this fails, the length shall be rejected.

S2. Intergranular Corrosion Bend Test

S2.1 One intergranular corrosion bend test shall be made on a welded section from one end of one length from each 2500 ft (760 m) or fraction thereof from each heat of steel or as specified by the purchaser. The specimen shall be bent so that the location of weld is at the point of maximum bend. The method of testing shall be in accordance with Practice E of Practices A 262.

S3. Packaging Requirements

S3.1 The ends shall be protected with wooden or plastic plugs.

S4. Hydrostatic Test

S4.1 Each length shall be subjected to a hydrostatic test in accordance with Specification A 999/A 999M, section on Hydrostatic Test Requirements.

S5. Flattening Test

S5.1 One flattening test shall be made to represent each lot (see Note 1) of finished product. Crop ends may be used.

S5.2 Evidence of laminated or unsound material that is revealed during the flattening test shall be cause for rejection.

S5.3 Superficial ruptures resulting from surface imperfections shall not be cause for rejection.

S5.4 A section of welded pipe not less than 4 in. (100 mm) in length shall be flattened cold between parallel plates in two steps. The weld shall be placed 90° from the direction of the applied force. During the first step, which is a test for ductility, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than one half of the outside diameter of the pipe. During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet.

Designation: A 774/A 774M – 06

Standard Specification for As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperatures[1]

This standard is issued under the fixed designation A 774/A 774M; 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 covers five grades of as-welded, wrought austenitic stainless steel fittings for low-pressure piping and intended for low and moderate temperatures and general corrosive service. Users should note that certain corrosive conditions may restrict the use of one or more grades. For applications requiring a product that requires heat treatment or full pressure rating, refer to Specification A 403/A 403M. The term "fittings" applies to butt and socket welding parts such as 45° and 90° elbows, tees, reducers, wyes, laterals, crosses, and stub ends.

1.2 This specification covers as-welded fittings 3 through 48 in. [75 through 1225 mm] in outside diameter and in nominal wall thicknesses 0.062 through 0.500 in. [1.6 through 12.7 mm]. Table 1 and Table 2 list the common diameters and nominal thicknesses of fittings in this specification.

1.3 This specification does not apply to cast fittings. Cast austenitic steel fittings are covered by Specification A 351/A 351M.

1.4 Optional supplementary requirements are provided for fittings where a greater degree of examination is desired. These supplementary requirements call for additional tests. When desired, one or more of these may be specified in the order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 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.

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A 960/A 960M, the following list of standards apply to this specification:

2.2 *ASTM Standards:* [2]

A 240/A 240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

A 351/A 351M Specification for Castings, Austenitic, for Pressure-Containing Parts

A 403/A 403M Specification for Wrought Austenitic Stainless Steel Piping Fittings

A 960/A 960M Specification for Common Requirements for Wrought Steel Piping Fittings

E 527 Practice for Numbering Metals and Alloys (UNS)

2.3 *ASME Standard:*

Section IX , Welding Qualtifications, ASME Boiler and Pressure Vessel Code[3]

2.4 *MSS Standard:*

SP 43 Wrought Stainless Steel Butt Welding Fittings[4]

2.5 *AWS Standards:*

A5.4 Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes[5]

A5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes[5]

2.6 *SAE Standard:*

J1086 Unified Numbering System for Metals and Alloys[6]

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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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] 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.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

[4] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602.

[5] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.

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

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

TABLE 1 Common Tubular Fittings Sizes, Outside Diameter[A]

in. [mm]	in. [mm]
3 [76]	12¾ [325]
3½ [90]	14 [355]
4 [100]	16 [405]
4½ [115]	18 [460]
6 [150]	20 [510]
6⅝ [170]	24 [610]
8 [205]	30 [760]
8⅝ [220]	36 [915]
10 [255]	40 [1015]
10¾ [275]	42 [1070]
12 [305]	48 [1220]

[A] Other sizes may be furnished provided they comply with all other requirements of this specification.

TABLE 2 Common Tubular Fittings Nominal Thicknesses[A]

in. or gage	in.	[mm]
16 gage	0.062	[1.6]
14 gage	0.078	[2.0]
12 gage	0.109	[2.8]
11 gage	0.125	[3.2]
10 gage	0.140	[3.6]
8 gage	0.172	[4.4]
3⁄16 in.	0.187	[4.8]
¼ in.	0.250	[6.4]
5⁄16 in.	0.312	[8.0]
⅜ in.	0.375	[9.5]
½ in.	0.500	[12.5]

[A] Other thicknesses may be furnished provided they comply with all other requirements of this specification.

3. Ordering Information

3.1 See Specification A 960/A 960M and the following:

3.1.1 Dimensions (outside diameter and specified wall thickness, see Table 1 and Table 2),

3.1.2 Grade (Table 3), and

3.1.3 End use, if known.

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 960/A 960M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 960/A 960M constitutes non-conformance with this specification. In case of a conflict between the requirements of this specification and Specification A 960/A 960M, this specification shall prevail.

5. Manufacture

5.1 The fittings shall be made from flat-rolled steel, such as in Specification A 240/A 240M. The flat rolled steel shall be in the solution annealed condition unless other heat treat conditions are agreed upon by the manufacturer and the purchaser. The fittings shall be formed by a hot or cold process, and welded by a shielded welding process with or without the addition of filler metal.

5.2 Fittings shall be furnished clean and free of scale.

5.3 *Welding*:

5.3.1 The joints shall be full penetration double-welded or single-welded butt joints employing fusion-welding processes with or without the addition of filler metal as defined under 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. Welding procedures and welding operators shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

5.3.2 For fittings employing multiple passes, the root-pass may be made without the addition of filler metal.

5.3.3 The alloy content (chromium, nickel, molybdenum, columbium, and tantalum) of the deposited weld metal shall conform to that required of the base metal or for equivalent weld metal as given in the AWS filler metal specification A5.4 or A5.9, except that, when welding on Types 304L base metal, the deposited weld metal shall correspond, respectively, to AWS Types E308L (ER308L) and, when welding on Type 321 base metal, the weld metal shall correspond to AWS Types E347 (ER347 or ER321).

6. Chemical Composition

6.1 The steel shall conform to requirements of chemical composition for the respective material prescribed in Table 3 and Table 4.

6.2 The steel shall not contain any unspecified elements for the ordered grade to the extent that it conforms to the

TABLE 3 Chemical Requirements

NOTE—Where an ellipsis (...) appears in this table, there is no requirement.

Grade	Composition, %											
	UNS Designation[A]	Carbon, max[B]	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Chromium	Nickel	Molybdenum	Titanium	Columbium plus Tantalum	Nitrogen, max
TP 304L	S30403	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	. . .	. . .	. . .	0.10
TP 316L	S31603	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	. . .	. . .	0.10
TP 317L	S31703	0.030	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	. . .	. . .	0.10
TP 321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	C	. . .	. . .
TP 347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	D	. . .

[A] New designation established in accordance with Practice E 527 and SAE J1086.
[B] The carbon analysis shall be reported to the nearest 0.01 % except for the low carbon (0.030) types, that shall be reported to the nearest 0.001 %.
[C] Ti = 5X(C+N) – 0.70.
[D] The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.10 %.

TABLE 4 Product Analysis Tolerances[A]

Element	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	0.005
Manganese	0.040
Phosphorus	0.010
Sulfur	0.005
Silicon	0.050
Chromium	0.200
Nickel	0.100
Molybdenum	0.100
Nitrogen	0.005

[A] This table does not apply to heat analysis.

requirements of another grade for which that element is a specified element having a required minimum content.

6.3 Mill certificates of analysis of each heat of steel shall be furnished on request.

7. Mechanical Properties

7.1 The material used in making these fittings shall conform to the test requirements listed in Table 5 for the specified grade. Mechanical tests made on the sheet or plate by the manufacturer shall qualify the sheet or plate material.

7.2 Mechanical properties of fittings made to this specification are not verified unless specific tests and limits have been agreed upon between the purchaser and manufacturer.

8. Heat Treatment

8.1 Heat treatment is not required (see 16.1).

9. Permissible Variations in Nominal Dimensions

9.1 Refer to MSS SP 43 for tolerances for fittings covered by this specification. For fittings not covered in MSS SP 43 (wyes and laterals) acceptance limits must be agreed upon between the purchaser and manufacturer.

10. Hydrostatic Tests

10.1 Hydrostatic testing of the fittings is not required by this specification.

11. Surface Quality

11.1 See Specification A 960/A 960M.

11.2 When the removal of a surface discontinuity reduces the wall thickness below 87½ % of the specified nominal wall thickness at any point, the fitting shall be subject to rejection or to repair as provided in Section 14.

12. Inspection

12.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being furnished in accordance with the specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to.

12.2 Other tests, when required by agreement, shall be made from material of the lots covered in the order.

NOTE 1—A lot shall consist of all fittings of the same type, size, and wall thickness, manufactured from one heat of material and using one lot number of electrode or one heat of weld wire.

13. Repair of Defects

13.1 Injurious defects that are deeper than the minimum specified in Section 12 may be repaired with the approval of the purchaser. Such defects shall be entirely removed by either chipping, machining, or grinding before welding. Rewelding shall be in accordance with 5.3 of this specification.

14. Rejection and Rehearing

14.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for rehearing.

14.2 Fittings that develop defects in shop working or application operations may be rejected. Upon rejection the manufacturer shall be notified in writing.

15. Certification

15.1 See Specification A 960/A 960M.

16. Product Marking

16.1 Each fitting shall be legibly marked with the manufacturer's name or brand, the schedule number or pressure class or thickness, the specified size, the specification number, the grade of material listed in Table 1, the heat number or manufacturer's heat identification, and the letters "HT-O" to indicate that there has been no heat treating after welding or forming.

NOTE 2—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component complies with the specification.

TABLE 5 Mechanical Test Requirements

Type[A]	UNS Designation	Tensile Strength		Yield Strength		Elongation in 2 in. [50 mm], min, %	Hardness, max[B]	
		ksi	[MPa]	ksi	[MPa]		Brinell	Rockwell B
304L	S30403	70-95	485-655	25	170	40.0	183	88
316L	S31603	70-95	485-655	25	170	40.0	217	95
317L	S31703	75-100	515-690	30	205	35.0	217	95
321	S32100	75-100	515-690	30	205	40.0	217	95
347	S34700	75-100	515-690	30	205	40.0	202	92

[A] Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).
[B] Either Brinell or Rockwell B Hardness is permissible.

16.2 The specification year of issue and revision letter, if any, are not required for product marking.

17. Packaging

17.1 The manufacturer shall box, crate, or package in secure lifts or bundles to ensure safe delivery. If specified, the ends shall be protected with wooden or plastic plugs. Special packaging requiring extra operations other than those above must be specified by the purchaser.

18. Keywords

18.1 austenitic stainless steel; corrosive service applications; pipe fittings-steel; piping applications; stainless steel fittings; temperature service applications-low

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not be considered unless specified in the order, in which event, any or all of the supplementary tests specified in Specification A 960/A 960M shall be made at the place of manufacture, unless otherwise agreed upon. The tests specified shall be witnessed by the purchaser's inspector before shipment of material if so specified in the order.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 774/A 774M – 02, that may impact the use of this specification. (Approved March 1, 2006)

(*1*) Changed "T*i*" to "Ti" in Note C of Table 3.

Designation: A 758/A 758M – 00 (Reapproved 2005)

Standard Specification for Wrought-Carbon Steel Butt-Welding Piping Fittings with Improved Notch Toughness[1]

This standard is issued under the fixed designation A 758/A 758M; 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 covers wrought-carbon steel butt-welding seamless or welded fittings specially processed to ensure better notch toughness than that to be expected in fittings manufactured to the requirements of Specification A 234/A 234M.

1.1.1 Included are elbows, caps, tees, reducers, and other type fittings covered by ASME B 16.9.

1.1.2 Heat treatment is required for all fittings.

1.1.3 Fittings with mandatory radiographic examination of welds are included.

1.1.4 Supplementary requirements are provided for use when additional testing or examination is desired.

1.1.5 Cast fittings, and fittings formed from all weld metal, are not included.

1.2 Several type of fittings are provided, as follows:

Type	Heat Treatment Required	Weld Seam Finish (5.3.2)	Radiography Required?
30	normalize	UW-35	no
31	normalize	UW-35	yes
32	normalize	UW-35 and ground flush	yes
40	normalize and temper	UW-35	no
41	normalize and temper	UW-35	yes
42	normalize and temper	UW-35 and ground flush	yes
50	quench and temper	UW-35	no
51	quench and temper	UW-35	yes
52	quench and temper	UW-35 and ground flush	yes

1.3 It shall be the responsibility of the purchaser to determine whether material meeting the requirements of this specification is satisfactory for the service application.

1.4 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 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.

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A 960/A 960M, the following list of standards apply to this specification:

2.2 *ASTM Standards:* [2]

A 234/A 234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 960/A 960M Specification for Common Requirements for Wrought Steel Piping Fittings

E 165 Test Method for Liquid Penetrant Inspection Method

E 709 Guide for Magnetic Particle Examination

2.3 *ASME Boiler and Pressure Vessel Code (ASME Code):*[3]

Section VIII, Division 1 Pressure Vessels

Section IX , Welding and Brazing Qualifications

2.4 *ASME Standard:*

B 16.9 Standards for Steel Butt-Welding Fittings[3]

2.5 *ASNT Standard:*

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

3. Ordering Information

3.1 See Specification A 960/A 960M.

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 960/A 960M, including

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] 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.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

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

any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 960/A 960M constitutes non-conformance with this specification. In case of a conflict between the requirements of this specification and Specification A 960/A 960M, this specification shall prevail.

5. Materials and Manufacture

5.1 The steel shall be killed and shall be melted to a fine austenitic grain size practice.

5.2 The starting material shall be wrought and in the form of blooms, billets, slabs, forgings, bars, plates, sheets, seamless pipe or tube, or welded-with-filler-metal pipe or tube. Cast products shall not be used.

5.3 Any forming process, fusion-welding process, or combination of such processes, may be used.

5.3.1 All welding shall be fusion-welded in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code. Welding procedures, welders, and welding operators shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

5.3.2 All welded joints shall be finished in accordance with Paragraph UW-35 of Section VIII, Division 1, of the ASME Code.

5.3.3 Welded joints of Type 32, 42, and 52 shall be ground flush.

5.3.4 Welded joints of Types 31, 41, 51, 32, 42, and 52 shall be examined by radiography in accordance with the requirements of Paragraph UW-51 of Section VIII, Division 1, of the ASME Code, and shall conform to the requirements of Paragraph UW-51.

5.4 *Heat Treatment*—All fittings shall be heat treated subsequent to final welding and forming.

5.4.1 *Types 30, 31, and 32* fittings shall be normalized by uniformly heating to a temperature in the austenitizing range, but not to exceed 1700 °F [925 °C], and subsequently removed from the furnace and air-cooled individually to room temperature.

5.4.2 *Types 40, 41, and 42* fittings shall be normalized in accordance with 5.4.1. After normalizing, the fittings shall be tempered by heating to a temperature in the range from 1100 °F to 1200 °F [595 °C to 675 °C], soaking at that temperature for ½ h minimum per 1 in. [25 mm] of thickness, but not less than 15 min, and then air-cooled to room temperature.

5.4.3 *Types 50, 51, and 52* fittings shall be quenched-and-tempered by uniformly heating to a temperature in the austenitizing range, but not to exceed 1700 °F [925 °C], and then quenching in a liquid media from the austenitizing temperature to a temperature below 800 °F [425 °C]. After quenching, the fittings shall be reheated to a temperature in the range from 1100 °F to 1250 °F [595 °C to 675 °C], soaking at that temperature for ½ h minimum per 1 in. [25 mm] of thickness, but not less than 15 min, and then air-cooled to room temperature.

6. Chemical Composition

6.1 *Heat or Cast Analysis*— The results shall conform to the requirements for the applicable grade as specified in Table 1.

TABLE 1 Chemical Requirements

Element	Cast or Heat Analysis	Product Analysis
Carbon, max, %	0.27	0.30
Manganese, %	0.85–1.20	0.75–1.25
Phosphorus, max, %	0.035	0.040
Sulfur, max, %	0.035	0.040
Silicon, %	0.15–0.30	0.13–0.33
Vanadium, max, %	0.05	0.05
Residual elements[A,B]		
Chromium, max, %	0.25	0.25
Nickel, max, %	0.25	0.25
Molybdenum, max, %	0.08	0.08
Copper, max, %	0.35	0.35
Lead, max, %	0.05	0.05

[A] Individual limits of chromium, nickel, molybdenum, and copper may be exceeded by 0.05 % provided that their total does not exceed 0.90 % in both the heat and product analysis.

[B] These are not to be added to the melt and shall only occur as a result of unavoidable residuals from the melting stock.

6.2 *Product Analysis*—Product analysis may be made by the purchaser. The results shall conform to the requirements for the applicable grade as specified in Table 1.

6.3 The steel shall not contain any unspecified elements for the ordered grade to the extent that it conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

7. *Mechanical Requirements* Mechanical Requirements

7.1 *Tensile Requirements*:

7.1.1 The fittings, as represented by tensile test specimens taken subsequent to final heat treatment, shall conform to the requirements for the applicable grade as specified in Table 2.

7.1.2 *Number and Location of Specimens*:

7.1.2.1 *Lot*—For tension testing, a lot shall consist of the fittings from a heat, in each heat treatment charge, with nominal wall thicknesses within ¼ in. [6 mm] of the nominal thickness of the test specimen. In addition, for Types 32, 42, and 52, the lot definition shall include each heat or lot of weld metal. If heat treatment is performed in a continuous or batch-type furnace controlled within a range of plus-or-minus 25 °F [14 °C] and equipped with calibrated thermocouples and recording pyrometers, and records of heat treatment are maintained, all fittings heat treated in such a furnace are considered to be in one charge. For furnaces not so equipped and controlled, each batch constitutes a charge.

7.1.2.2 *Representative Test Piece*—For instances in which the tension test specimen cannot be obtained from a fitting due to size limitations, a representative test piece may be used. The test piece shall be from the same heat and shall be heat treated

TABLE 2 Tensile Requirements

	Grade 60	Grade 70
Tensile strength, ksi [MPa]	60 to 85 [415 to 585]	70 to 95 [485 to 635]
Yield strength,[A] min, ksi [MPa]	35 [240]	38 [260]
Elongation in 2 in. [50 mm], min, %		
Longitudinal	30	27
Transverse	22	20

[A] 0.2 % offset or 0.5 % EUL.

in the same heat treatment batch or charge as the fittings it represents, and shall have had approximately the same amount of working as the fittings. In addition, for fittings manufactured from bars, plate, or forgings, the test piece shall have a cross-section equal to or larger than the greatest cross-section of the fittings it represents. Test pieces representing fittings manufactured from pipe shall have a nominal outside diameter and wall thickness equal to that of the pipe from which the fitting was formed. Test pieces for fittings fabricated by welding or formed from welded pipe shall be prepared with the same welding procedure and from the same heat or lot of weld metal as the fitting it represents.

7.1.2.3 *Types 30, 31, 40, 41, 50, and 51*— One base-metal tension test specimen shall be tested from each lot. For fittings fabricated by welding, one transverse-weld tension test specimen shall also be made from each lot. One traverse-weld tension test specimen shall also be required from each lot for fittings formed from welded pipe if the weld in the welded pipe was not tested in the same heat treatment condition as the fittings.

7.1.2.4 *Types 32, 42, and 52*—One base-metal and one transverse-weld tension test specimen shall be tested from each lot. Fittings fabricated by welding or formed from welded pipe shall be tested as in 7.1.2.3.

7.1.2.5 Tension test specimens shall be taken from an integral part of the fitting where practicable. All base-metal tension tests shall be conducted in the longitudinal direction. Weld metal specimens shall be taken transverse to the weld.

7.1.2.6 Tests shall be conducted in accordance with Test Methods and Definitions A 370. Yield strength shall be determined either by the 0.2 % offset method or the 0.5 % extension-under-load method.

7.2 *Transverse Guided Weld Bend Tests—Welded Fittings Only*:

7.2.1 *Number of Tests*:

7.2.1.1 *Lot*—A lot shall be as defined in 7.1.2.1.

7.2.1.2 One guided face-bend and one guided root-bend test shall be made to represent each lot for fittings with a nominal wall thickness of ⅜ in. [10 mm] and less. For fittings with a nominal wall thickness greater than ⅜ in. [10 mm], one guided side-bend test shall be made to represent each lot.

7.2.2 *Test Specimen Location and Orientation*—Full thickness specimens shall be taken transverse to the weld, subsequent to final heat treatment, in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

7.2.3 *Requirement*—The guided-bend test specimen shall not have any cracks or other open defects exceeding ⅛ in. [3 mm], measured in any direction on the convex surface of the specimen after bending. Cracks occurring on the corners of the specimen during testing shall not be considered unless there is definite evidence that they result from slag inclusions or other internal defects.

8. Dimensions

8.1 Butt-welded fittings shall conform to the dimensions and tolerances specified in ASME B 16.9.

9. Surface Quality

9.1 See Specification A 960/A 960M.

10. Radiographic Examination

10.1 *Types 31, 32, 41, 42, 51, and 52* fittings shall have the entire length of each weld joint examined radiographically in accordance with Paragraph UW-51 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code.

10.2 Radiographic examination may be performed prior to final heat treatment.

10.3 Personnel performing radiographic examination shall be qualified and certified in accordance with SNT-TC-1A-1984, or with the approval of the purchaser, in accordance with another nationally-accepted standard which covers the qualification and certification of radiographic examination personnel.

11. Rework and Retreatment

11.1 See Specification A 960/A 960M.

11.2 *Repair Welding—Parent Metal*:

11.2.1 Repair welding by the manufacturer is permissible for parts made to dimensional standards, in ASME or equivalent standards.

11.2.2 Prior approval of the purchaser shall be required to weld repair special parts made to the purchaser's requirements.

11.2.3 Welding shall produce low hydrogen in the weldment.

11.2.4 The product shall be heat treated in accordance with Section 5 after weld repair.

12. Inspection

12.1 The manufacturer shall afford the purchaser's inspectors all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to.

13. Rejection and Rehearing

13.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

13.2 Fittings that develop defects in shop working or application operations may be rejected. Upon rejection, the manufacturer shall be notified in writing.

14. Certification

14.1 See Specification A 960/A 960M.

15. Product Marking

15.1 See Specification A 960/A 960M.

15.2 The marking shall be legibly forged, stamped, stencilled, or otherwise suitably marked on each fitting. Use low-stress stamps for all metal stamping. The marking shall not cause cracks or reduce the wall thickness of the product below the minimum allowed.

15.3 *Bar Coding*—Bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

16. Packaging, Package Marking, and Loading for Shipment

16.1 See Specification A 960/A 960M.

17. Keywords

17.1 low; pipe fittings; piping applications; pressure containing parts; steel; temperature service applications

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Product Analysis

S1.1 A product analysis shall be made for each heat of base material, by the manufacturer of the fitting, to determine the element percentage points specified in Table 1.

S1.2 The determined chemical composition shall be reported to the purchaser, or his representative, and shall conform to the product analysis requirements of Table 1.

S1.3 A product analysis shall also be made of the deposited weld metal. The weld metal analysis shall conform to the requirements of the Welding Procedure Specification, Section IX of the ASME Boiler and Pressure Vessel Code.

S2. Charpy V-Notch Test

S2.1 Charpy V-notch test shall be made as specified on the order. The test temperature, acceptance criteria, number of tests, and location of tests (whether from base-metal, weld metal, or heat-affected zone of welds) shall be specified.

S3. Pressure Test

S3.1 The completed fitting shall be pressure tested with water at 1.5 times design pressure for 10 min and shall not leak or show evidence of reduced service.

S4. Magnetic Particle Examination—Base Metal

S4.1 All accessible surfaces of the fittings shall be examined in accordance with Guide E 709. Accessible is defined as all outside surfaces, all inside surfaces of fittings 24 in. [610 mm] in diameter and greater, and inside surfaces of fittings less than 24 in. [610 mm] in diameter, for a distance of one diameter from the ends.

S4.2 *Acceptance Criteria*—The following indications are unacceptable:

S4.2.1 Linear indications greater than (*1*) 1⁄16 in. [1.6 mm] long for materials less than 5⁄8 in. [16 mm] thick; (*2*) 1⁄8 in. [3.2 mm] long for materials from 5⁄8 in. [16 mm] thick to below 2 in. [50 mm] thick, and; (*3*) 3⁄16 in. [5 mm] long for materials 2 in. [50 mm] thick or greater.

S4.2.2 Rounded indications with dimensions greater than (*1*) 1⁄8 in. [3.2 mm] for thicknesses less than 5⁄8 in. [16 mm] and, (*2*) 3⁄16 in. [5 mm] for thicknesses 5⁄8 in. [16 mm] and greater.

S4.2.3 Four or more indications in any line separated by 1⁄16 in. [1.6 mm] or less edge to edge.

S4.2.4 Ten or more indications located in any 6 in.^{2} [4000 mm^2] of surface, with major dimension not to exceed 6 in. [150 mm] when the major dimension is oriented so that the area includes the maximum number of indications being evaluated.

S4.3 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A-1984.

S5. Liquid Penetrant Examination of Base Metal

S5.1 All accessible surfaces of the fittings shall be examined in accordance with Test Method E 165. Accessible is defined in S4.1

S5.2 Acceptance criteria shall be in accordance with S4.2.

S5.3 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A-1984.

S6. Weld Repair Surface

S6.1 Area(s) to be repair-welded and weld repaired surface shall be magnetic particle inspected in accordance with Test Method A 275/A 275M in order to agree with the purchaser's acceptance criteria.

S6.2 Area(s) to be repair welded and weld repaired surface shall be liquid penetrant inspected in accordance with Test Method E 165 in order to agree with the purchaser's acceptance criteria.

S7. Weld Repair Imperfections

S7.1 These are not permitted without the purchaser's prior approval.

Designation: A 751 – 07a

Standard Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[1]

This standard is issued under the fixed designation A 751; 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.

INTRODUCTION

These test methods, practices, and terminology were prepared to answer the need for a single document that would include all aspects of obtaining and reporting the chemical analysis of steel, stainless steel, and related alloys. Such subjects as definitions of terms and product (check) analysis variations (tolerances) required clarification. Requirements for sampling, meeting specified limits, and treatment of data usually were not clearly established in product specifications.

It is intended that these test methods, practices, and terminology will contain all requirements for the determination of chemical composition of steel, stainless steel, or related alloys so that product specifications will need contain only special modifications and exceptions.

1. Scope*

1.1 These test methods, practices, and terminology cover definitions, reference methods, practices, and guides relating to the chemical analysis of steel, stainless steel, and related alloys. It includes both wet chemical and instrumental techniques.

1.2 Directions are provided for handling chemical requirements, product analyses, residual elements, and reference standards, and for the treatment and reporting of chemical analysis data.

1.3 These test methods, practices, and terminology apply only to those product standards which include these test methods, practices, and terminology, or parts thereof, as a requirement.

1.4 In cases of conflict, the product specification requirements shall take precedence over the requirements of these test methods, practices, and terminology.

1.5 Attention is directed to ISO/IEC 17025 when there may be a need for information on criteria for evaluation of testing laboratories.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[3]

E 50 Practices for Apparatus, Reagents, and Safety Considerations for Chemical Analysis of Metals, Ores, and Related Materials

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[3]

E 60 Practice for Analysis of Metals, Ores, and Related Materials by Molecular Absorption Spectrometry

E 212 Test Method for Spectrographic Analysis of Carbon and Low-Alloy Steel by the Rod-To-Rod Technique[3]

E 293 Test Method for Spectrographic Determination of Acid-Soluble Aluminum in Low-Alloy Steel by the Solution Technique[3]

E 322 Test Method for X-Ray Emission Spectrometric Analysis of Low-Alloy Steels and Cast Irons

E 327 Test Method for Optical Emission Spectrometric Analysis of Stainless Type 18-8 Steels by the Point-To-Plane Technique[3]

E 350 Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron

[1] These test methods, practices, and terminology are under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and are the direct responsibility of Subcommittee A01.13 on Mechanical and Chemical Testing and Processing Methods of Steel Products and Processes.

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[2] 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.

[3] Withdrawn.

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

E 352 Test Methods for Chemical Analysis of Tool Steels and Other Similar Medium- and High-Alloy Steels
E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
E 403 Method for Optical Emission Spetrometric Analysis of Carbon and Low-Alloy Steel by the Point-To-Plane Technique[3]
E 404 Test Method for Spectrographic Determination of Boron In Carbon and LowAlloy Steel by the Point-To-Plane Technique[3]
E 415 Test Method for Optical Emission Vacuum Spectrometric Analysis of Carbon and Low-Alloy Steel
E 421 Test Method for Spectrographic Determination of Silicon and Aluminum in High-Purity Iron[3]
E 485 Test Method for Optical Emission Vacuum Spectrometric Analysis of Blast Furnace Iron by the Point-to-Plane Technique
E 548 Guide for General Criteria Used for Evaluating Laboratory Competence[3]
E 572 Test Method for Analysis of Stainless and Alloy Steels by X-ray Fluorescence Spectrometry
E 663 Practice for Flame Atomic Absorption Analysis[3]
E 743 Guide for Spectrochemical Laboratory Quality Assurance[3]
E 851 Practice for Evaluation of Spectrochemical laboratories[3]
E 882 Guide for Accountability and Quality Control in the Chemical Analysis Laboratory
E 1019 Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel and in Iron, Nickel, and Cobalt Alloys
E 1024 Guide for Chemical Analysis of Metals and Metal Bearing Ores by Flame Atomic Absorption Spectrophotometry[3]
E 1063 Test Method for X-Ray Emission Spectrometric Determination of Cerium and Lanthanum in Carbon and Low-Alloy Steel[3]
E 1086 Test Method for Optical Emission Vacuum Spectrometric Analysis of Stainless Steel by Point-to-Plane Excitation Technique
E 1087 Practice for Sampling Molten Steel From a Ladle Using an Immersion Sampler to Produce a Specimen for Emission Spectrochemical Analysis [3]
E 1097 Guide for Direct Current Plasma Emission Spectrometry Analysis
E 1184 Practice for Electrothermal (Graphite Furnace) Atomic Absorption Analysis
E 1282 Guide for Specifying the Chemical Compositions and Selecting Sampling Practices and Quantitative Analysis Methods for Metals, Ores, and Related Materials
E 1329 Practice for Verification and Use of Control Charts in Spectrochemical Analysis

2.2 *ISO Standards*[4]

ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories

3. Terminology

3.1 *Definitions:*

3.1.1 *Pertaining to Analyses*:

3.1.1.1 *cast or heat (formerly ladle) analysis*—applies to chemical analyses representative of a heat of steel as reported to the purchaser and determined by analyzing a test sample, preferably obtained during the pouring of the steel, for the elements designated in a specification.

3.1.1.2 *product, check or verification analysis*—a chemical analysis of the semifinished or finished product, usually for the purpose of determining conformance to the specification requirements. The range of the specified composition applicable to product analysis is normally greater than that applicable to heat analysis in order to take into account deviations associated with analytical reproducibility (Note 1) and the heterogeneity of the steel.

NOTE 1—All of the chemical analysis procedures referenced in this document include precision statements with reproducibility data with the exception of Test Methods E 30.

3.1.1.3 *product analysis tolerances (*Note 2*)*—a permissible variation over the maximum limit or under the minimum limit of a specified element and applicable only to product analyses, not cast or heat analyses.

NOTE 2—The term "analysis tolerance" is often misunderstood. It does not apply to cast or heat analyses determined to show conformance to specified chemical limits. It applies only to product analysis and becomes meaningful only when the heat analysis of an element falls close to one of the specified limits. For example, stainless steel UNS 30400 limits for chromium are 18.00 to 20.00 %. A heat that the producer reported as 18.01 % chromium may be found to show 17.80 % chromium by a user performing a product analysis. If the product analysis tolerance for such a chromium level is 0.20 %, the product analysis of 17.80 % chromium would be acceptable. A product analysis of 17.79 % would not be acceptable.

3.1.1.4 *proprietary analytical method*—a non-standard analytical method, not published by ASTM, utilizing reference standards traceable to the National Institute of Standards and Technology (NIST) (when available) or other sources referenced in Section 10.

3.1.1.5 *referee analysis*—performed using ASTM methods listed in 9.1.1 and NIST reference standards or methods and reference standards agreed upon between parties. The selection of a laboratory to perform the referee analysis shall be a matter of agreement between the supplier and the purchaser.

3.1.1.6 *certified reference material*—a specimen of material specially prepared, analyzed, and certified for chemical content under the jurisdiction of a recognized standardizing agency or group, such as the National Institute of Standards and Technology, for use by analytical laboratories as an accurate basis for comparison. Reference samples should bear sufficient

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

resemblance to the material to be analyzed so that no significant differences are required in procedures or corrections (for example, for interferences or inter-element effects).

3.1.1.7 *working reference materials*—reference materials used for routine analytical control and traceable to NIST standards and other recognized standards when appropriate standards are available.

3.1.2 *Pertaining to Elements*:

3.1.2.1 *intentionally added unspecified element*—an element added in controlled amounts at the option of the producer to obtain desirable characteristics.

3.1.2.2 *residual element*—a specified or unspecified element, not intentionally added, originating in raw materials, refractories, or air.

3.1.2.3 *specified element*—an element controlled to a specified range, maximum or minimum, in accordance with the requirements of the product specification.

3.1.2.4 *trace element*—a residual element that may occur in very low concentrations, generally less than 0.01 %.

4. Concerning the Specification of Chemical Composition Requirements

4.1 It is recommended that Guide E 1282 be consulted as a guide for specifying the chemical compositions for steels.

4.2 The recommended practice for specifying chemical composition limits is to limit the number of significant figures for each element so that the number of figures to the right of the decimal point conforms to the following:

Chemical Concentration		Maximum Number of Figures to the Right of the Decimal Point
Up to 0.010 %, incl.	—	0.XXXX or may be expressed as ppm
Over 0.010 % to 0.10 %, incl.	—	0.XXX
Over 0.10 % to 3.0 %, incl.	—	0.XX
Over 3.0 %	—	0.X

4.3 For those cases in which the composition range spans either 0.10 % or 3.0 %, the number of figures to the right of the decimal is to be determined by that indicated by the upper limit.

4.4 Technical considerations may dictate the employment of less than the number of figures to the right of the decimal as previously recommended.

NOTE 3—The recommendations should be employed to reduce the number of significant figures, such as from 18.00 % to 18.0 %, but a significant figure should never be added unless there is a technical reason for so doing.

5. Cast or Heat Analysis

5.1 The producer shall perform analyses for those elements specified in the material specification. The results of such analyses shall conform to the requirements specified in the material specification.

5.1.1 For multiple heats, either individual heat or cast analysis or an average heat or cast analysis shall be reported. If significant variations in heat or cast size are involved, a weighted average heat or cast analysis, based on the relative quantity of metal in each heat or cast, shall be reported.

5.1.2 For consumable electrode remelted material, a heat is defined as all the ingots remelted by the same process from a primary heat. The heat analysis shall be obtained from one remelted ingot, or the product of one remelted ingot, from each primary melt. If this heat analysis does not meet the heat analysis requirements of the specification, one sample from the product of each remelted ingot shall be analyzed, and the analyses shall meet the heat analysis requirements.

5.2 If the test samples taken for the heat analysis are lost, inadequate, or not representative of the heat, a product analysis of the semifinished or finished product may be used to establish the heat analysis.

5.2.1 If a product analysis is made to establish the heat analysis, the product analysis shall meet the specified limits for heat analysis and the product analysis tolerances described in Section 6 do not apply.

6. Product Analysis Requirements

6.1 For product analysis, the range of the specified chemical composition is normally greater (designated product analysis tolerances) than that applicable to heat analyses to take into account deviations associated with analytical reproducibility and the heterogeneity of the steel. If several determinations of any element in the heat are made, they may not vary both above and below the specified range.

6.2 Product analysis tolerances may not be used to determine conformance to the specified heat or cast analysis unless permitted by the individual material specification.

6.3 Product analysis tolerances, where available, are given in the individual material specifications or in the general requirement specifications.

7. Unspecified Elements (Note 4)

7.1 Reporting analyses of unspecified elements is permitted.

NOTE 4—All commercial metals contain small amounts of various elements in addition to those which are specified. It is neither practical nor necessary to specify limits for every unspecified element that might be present, despite the fact that the presence of many of these elements is often routinely determined by the producer.

7.2 Analysis limits shall be established for specific elements rather than groups of elements such as "all others," " rare earths," and "balance."

8. Sampling

8.1 *Cast or Heat Analyses*:

8.1.1 Samples shall be taken, insofar as possible, during the casting of a heat, at a time which, in the producer's judgment, best represents the composition of the cast.

8.1.2 In case the heat analysis samples or analyses are lost or inadequate, or when it is evident that the sample does not truly represent the heat, representative samples may be taken from the semifinished or finished product, in which case such samples may be analyzed to satisfy the specified requirements. The analysis shall meet the specified limits for heat analysis.

8.2 *Check, Product, or Verification Analyses*—Unless otherwise specified, the latest revision of Practice E 59 shall be used as a guide for sampling.

9. Test Methods

9.1 This section lists some test methods that have been found acceptable for chemical analysis of steels.

9.1.1 The following ASTM wet chemical test methods have been found acceptable as referee test methods and as a base for standardizing instrumental analysis techniques:

Test Methods		General Description
E 30	—	antecedent to Test Methods E 350 through E 354
E 350	—	the basic wet chemical procedure for steels
E 352	—	wet chemical procedure for tool steels
E 353	—	wet chemical procedure for stainless steels
E 354	—	wet chemical procedure for high nickel steels
E 1019	—	determination of carbon, sulfur, nitrogen, oxygen, and hydrogen, in steel and in iron, nickel, and cobalt alloys

9.1.2 The following ASTM instrumental test methods, practices, and guides may be employed for chemical analysis of steels or may be useful as a guide in the calibration and standardization of instrumental equipment for routine sampling and analysis of steels:

Standard		General Description
E 50	—	apparatus, reagents, and safety
E 60	—	photometric and spectrophotometric work
E 212	—	spectrographic analysis of steels (rod-to-rod technique)
E 293	—	spectrographic analysis of acid-soluble aluminum
E 322	—	x-ray fluorescence for steels
E 327	—	spectrometric analysis of stainless steels
E 403	—	spectrometric analysis of steels
E 404	—	spectrographic determination of steels for boron (point-to-plane technique)
E 415	—	vacuum spectrometric analysis of steels
E 421	—	spectrographic determination of silicon and aluminum in high-purity iron
E 485	—	optical emission vacuum spectrometric analysis of blast furnace iron by the point-to plane technique
E 572	—	x-ray emission spectrometric analysis of stainless steels
E 663	—	flame atomic absorption
E 882	—	accountability and quality control
E 1019	—	determination of carbon, sulfur, nitrogen, oxygen, and hydrogen in steel and in iron, nickel, and cobalt alloys
E 1024	—	flame atomic absorption
E 1063	—	x-ray emission spectrometric determination of cerium and lathanum in carbon and low-alloy steels
E 1086	—	optical emission vacuum spectrometric analysis of stainless steel by the point-to plane excitation technique
E 1087	—	sampling
E 1097	—	direct current plasma spectroscopy
E 1184	—	graphite furnace atomic absorption
E 1282	—	selecting sampling practices and analysis methods
E 1329	—	verification and use of control charts

9.2 The following are some of the commonly accepted techniques employed for routine chemical analysis of steels. These routine analyses are the basis for the producers' quality control/assurance programs. Proprietary methods are permissible provided the results are equivalent to those obtained from standard methods when applicable.

9.2.1 Analysis of stainless steels using x-ray fluorescence spectroscopy (XRF). See Table 1 for normal elements and ranges for stainless steels.

TABLE 1 Normal Elements and Ranges for Stainless Steels Using X-Ray Fluorescence Spectroscopy

Element	Ranges %	Element	Ranges %
MN	0.005–15.0	Cu	0.005–4.0
P	0.001–0.15	Cb	0.005–3.0
Si	0.005–5.0	V	0.005–2.0
Cr	0.01–26.0	Ti	0.005–2.5
Ni	0.01–36.0	Co	0.005–4.0
Al	0.002–5.5	Sn	0.002–0.20
Mo	0.005–8.0	W	0.005–3.0

TABLE 2 Normal Elements and Ranges for Stainless Steels Using Spark Emission Spectroscopy

C	0.004–5.0	V	0.005–2.0
S	0.0005–0.1	Ti	0.005–2.5
N_2	0.0020–0.3	Co	0.005–4.0
MN	0.005–15.0	Sn	0.001–0.20
P	0.001–1.5	W	0.005–3.0
Si	0.005–5.0	Pb	0.002–0.05
Cr	0.01–26.0	B	0.0005–0.05
Ni	0.01–36.0	Ca	0.0002–0.01
Al	0.001–5.5	Mg	0.001–0.01
Mo	0.005–8.0	Ce	0.001–0.2
Cu	0.005–4.0	Zr	0.001–0.1
Cb	0.005–3.0	Ta	0.005–0.5

9.2.2 Analysis of stainless steels using spark emission spectroscopy (OES). See Table 2 for normal elements and ranges for stainless steels.

9.2.3 Analysis of solutions using an atomic absorption spectrophotometer.

9.2.4 Analysis of solutions using an inductively coupled plasma emission spectrometer.

9.2.5 Determination of carbon or sulfur, or both, by combustion (in oxygen) and measurement of CO_2 or SO_2, or both, by thermal conductivity or infrared detectors.

Element	Ranges %	Element	Ranges %
C	0.002 – 5.0	S	0.0005 – 0.1

9.2.6 Determination of nitrogen and oxygen by fusion (in a helium atmosphere) and measurement of N_2 by thermal conductivity and oxygen by measurement of CO by infrared or thermal conductivity detectors.

Element	Ranges %
N_2	0.0005 – 0.3
O_2	0.0008 – 0.02

9.2.7 Analysis of solutions using inductively coupled plasma emission spectroscopy (ICP) or direct plasma emission spectroscopy (DCP). Normal elements and ranges for stainless steels are as follows:

Element	Ranges %
B	0.0002 – 0.01
Ca	0.0002 – 0.01
Mg	0.0002 – 0.01
Ce	0.001 – 0.2
Zr	0.001 – 0.1
Ta	0.005 – 0.5
La	0.001 – 0.01

9.3 There are additional common techniques often used for chemical analysis of standards for instrument analysis such as: polarographic analysis, ion exchange separations, radioactivation, and mass spectrometry.

10. Reference Materials

10.1 For referee analyses, reference standards of a recognized standardizing agency shall be employed with preference given to NIST standard reference materials when applicable. (NIST does not produce reference standards suitable for all elements or all alloys.[5])

[5] Some sources of reference materials are listed in ASTM Data Series Publication No. DS2, issued 1963.

10.1.1 When standard reference materials for certain alloys are not available from NIST, reference materials may be produced by employing ASTM standard procedures and NIST standard reference materials to the extent that such procedures and reference standards are available. Several independent laboratories should be used for certification of these standards and their results statistically reviewed and merged.

10.1.2 Methods not published by ASTM such as a definitive analytical method may be used when the method is validated by analyzing certified reference materials along with the candidate reference material. Examples of definitive analytical methods include gravimetric, coulometry, titrimetric based on normality, and mass spectrometry.

10.2 Working reference materials may be used for routine analytical control.

11. Significant Numbers

11.1 Laboratories shall report each element to the same number of significant numbers as used in the pertinent material specifications.

11.2 When a chemical determination yields a greater number of significant numbers than is specified for an element, the result shall be rounded in accordance with Section 12.

12. Rounding Procedure

12.1 To determine conformance with the specification requirements, an observed value or calculated value shall be rounded in accordance with Practice E 29 to the nearest unit in the last right-hand place of values listed in the table of chemical requirements.

12.2 In the special case of rounding the number "5" when no additional numbers other than "0" follow the "5", rounding shall be done in the direction of the specification analysis limits if following Practice E 29 would cause rejection of material.

13. Records

13.1 In addition to the test data requested, the test records shall contain the following information as appropriate:

13.1.1 Description of the material tested, for example, heat number, grade of material, product specification.

13.1.2 Test method(s) or unambiguous description of the nonstandard method(s) used.

14. Keywords

14.1 cast analysis; chemical analysis; heat analysis; product analysis; reference materials

APPENDIX

(Nonmandatory Information)

X1. QUALITY ASSURANCE FOR VALIDITY OF ANALYTICAL RESULTS

X1.1 The requirements embodied in Guide E 548, ISO/IEC 17025, and E 851 provide generic requirements for production of valid chemical-analysis results.

X1.2 Additional pertinent standards for improving the competency of chemical analysis laboratories are included in Guides E 743 and E 882.

X1.3 Keys to improving validity of chemical analytical results are as follows:

X1.3.1 Replication of sampling and testing to improve the precision of results;

X1.3.2 Use of reference materials is crucial to accurate results;

X1.3.3 Instrumentation that is appropriate and properly maintained; and

X1.3.4 Personnel who are properly trained, ethical chemists or technicians and who work with properly documented, current standards.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 751 – 07) that may impact the use of this standard. (Approved June 1, 2007.)

(*1*) Revised table in 4.2.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 751 – 01 (2006)) that may impact the use of this standard. (Approved April 1, 2007.)

(*1*) Replaced referenced document for laboratory evaluation.

Designation: A 733 – 03

Standard Specification for Welded and Seamless Carbon Steel and Austenitic Stainless Steel Pipe Nipples[1]

This standard is issued under the fixed designation A 733; 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

1.1 This specification covers the requirements for welded and seamless carbon steel pipe nipples, black and zinc-coated (hot-dip galvanized), and welded and seamless austenitic stainless steel pipe nipples in standard steel pipe sizes from ⅛to 12 in. inclusive, in standard or special lengths.

1.1.1 *Welded Carbon Steel*—Pipe nipples ordered under these requirements are intended for general uses, as described by Specification A 53.

1.1.2 *Seamless Carbon Steel*—Pipe nipples ordered under these requirements are intended for general and special uses, as described by the applicable Specifications A 53 and A 106 (see 4.1.1).

1.1.3 *Austenitic Stainless Steel*—Pipe nipples ordered under these requirements are intended for high-temperature and general corrosion service, as described by Specification A 312 (see 4.1.2).

1.1.4 The text for this specification contains notes and/or footnotes that provide explanatory material. Such notes and footnotes, excluding those in tables, do not contain any mandatory language.

2. Referenced Documents

2.1 *ASTM Standards:*

A 53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless[2]

A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service[2]

A 312 Specification for Seamless and Welded Austenitic Stainless Steel Pipes[2]

2.2 *American National Standards Institute Standards:*[3]

B1.20.1 Pipe Threads, General Purpose

B36.10 Standard for Welded and Seamless Wrought Steel Pipe

B36.19 Standard for Stainless Steel Pipe

3. Ordering Information

3.1 Information items to be considered, if appropriate, for inclusion in purchase orders are as follows:

3.1.1 Quantity (pieces),

3.1.2 Name of material (carbon steel or austenitic stainless steel pipe nipples) (see 4.1.1 and 4.1.2),

3.1.3 Method of pipe manufacture (continuous-welded, electric-resistance welded, or seamless). (see 4.1.1, Note 1),

3.1.4 Type and grade (if stainless steel),

3.1.5 Finish (carbon steel, black or galvanized),

3.1.6 Size (nominal and weight class or schedule number as shown in Table 1, or outside diameter and nominal wall),

3.1.7 Length (standard or special, see 4.3),

3.1.8 Specification number,

3.1.9 Certification of compliance, if required, and

3.1.10 Special requirements or exceptions to this specification.

3.2 In addition, when material is purchased for agencies of the U.S. Government, it shall conform to the Supplementary Requirements as defined herein when specified in the contract or purchase order.

4. Requirements

4.1 *Material and Weight*—Pipe nipples covered by this specification shall be made from new, hydrostatic-tested or NDE-tested pipe conforming to the requirements specified in 4.1.1 and 4.1.2.

4.1.1 *Carbon Steel*—Carbon steel pipe nipples shall be in accordance with the following:

Method of Pipe Manufacture	Specification
Welded (Note 1)	A 53
Seamless (Note 2)	A 53
	A 106

NOTE 1—Unless otherwise specified, continuous–welded nipples are furnished in sizes NPS 4 and under for standard and extra strong pipe, and NPS 2½ and under for Schedule 160 and double extra strong pipe. Welded nipples in sizes larger than that indicated for continuous–welded are electric resistance welded.

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Apr. 10, 2003. Published May 2003. Originally approved in 1976. Last previous edition approved in 2001 as A 733-01.

[2] *Annual Book of ASTM Standards*, Vol 01.01.

[3] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

TABLE 1 Pipe Nipple Sizes According to Weight of Nominal Pipe Sizes[A,B]

Weight	NPS Designator						
	⅛	¼	⅜	½ to 6	8	10	12
Standard (Schedule 40)	X	X	X	X	X	X	[C]
Extra strong (Schedule 80)	X	X	X	X	X	[D]	[C]
Schedule 160	...	...	...	X	X	X	X
Double extra strong	...	...	...	X	X	X	X

[A] A comprehensive listing of standardized pipe dimensions is contained in ANSI B36.10 and B36.19.
[B] Continuous-welded pipe is not made in sizes larger than NPS 4 (standard and extra strong) and larger than NPS 2½(Schedule 160 and double extra strong).
[C] NPS 12 standard and extra strong weight pipe do not have designated schedule numbers.
[D] NPS 10 extra strong pipe is Schedule 60, not Schedule 80.

4.1.2 *Austenitic Stainless Steel*—Austenitic stainless steel pipe nipples shall be in accordance with Specification A 312.

4.2 *Threads*—Pipe nipples shall be threaded on both ends with NPT taper pipe threads conforming to the requirements of ANSI B 1.20.1, except for "close" nipples where L 4 and V are shorter, due to fewer imperfect threads. It is standard manufacturing practice on all other nipple lengths to vary L 4 plus or minus two threads. All other dimensions, tolerances, and gaging practices remain the same as ANSI B 1.20.1, plus 5.3 of this specification.

4.2.1 Threads shall be right-hand on both ends, except when otherwise specified.

4.3 *Lengths*:

4.3.1 The standard lengths and sizes of nipples generally available are shown in Table 2. The availability of such nipples according to pipe size and weight is shown in Table 1.

4.3.2 Special lengths and sizes of nipples may be specified when required. Standard and special lengths shall conform to the tolerance requirements of 4.3.3.

4.3.3 Nipples with lengths up through 12 in. (304.8 mm) long shall have a length tolerance of ± 1⁄16 in. (1.6 mm). Nipples over 12 in. long shall have a tolerance of ± ⅛ in. (3.2 mm).

4.4 *End Finish*—The ends of the pipe nipples shall be chamfered on the outside at an angle of 35 ± 10 ° to the central axis. (It is the standard practice that the ⅛-in. (3.2-mm) nominal pipe size nipples are not chamfered.) Ends shall be cut reasonably square to the central axis. All burrs on the inside shall be removed.

4.5 *Galvanized Nipples*—Galvanized nipples ordered under this specification shall be made from pipe coated on the inside and outside by the hot-dip process. Threads and nipple ends are not galvanized.

5. Sampling and Inspection

5.1 *Sampling*—Samples of nipples sufficient to determine their conformance with the requirements of this specification shall be taken at random for each lot of nipples of the same pipe size, length, and material.

TABLE 2 Pipe Nipples by Length and Nominal Pipe Size

Type of Nipple	NPS Designator																	
	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½	3	3½	4	5	6	8	10	12
	Pipe Nipple Lengths, in.[A,B]																	
Close (cl)	¾	⅞	1	1⅛	1⅜	1½	1⅝	1¾	2	2½	2⅝	2¾	2⅞	3	3⅛	3½	3⅞	4½
	1½	1½	1½	1½	1½													
	2	2	2	2	2	2	2	2										
	2½	2½	2½	2½	2½	2½	2½	2½	2½									
	3	3	3	3	3	3	3	3	3	3	3							
	3½	3½	3½	3½	3½	3½	3½	3	3½	3½	3½							
	4	4	4	4	4	4	4	4	4	4	4	4	4					
	4½	4½	4½	4½	4½	4½	4½	4½	4½	4½	4½	4½	4½	4½	4½			
	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	
	5½	5½	5½	5½	5½	5½	5½	5½	5½	5½	5½	5½	5½	5½	5½	5½	5½	
	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Right and left	...	...	4	4	4	4	4	4	4	4	4	...	...	...	...	...	...	...

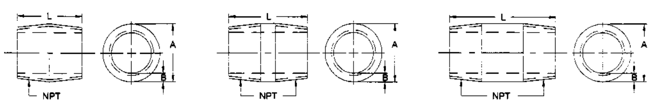
[A] Nipples shorter than close are not recommended for pressure application.
[B] 1 in. = 25.4 mm.

TABLE 3 Dash numbers for standard and extra strong steel pipe nipples

NOMINAL PIPE SIZE	⅛	¼	⅜	½	¾	1	1-¼	1-½	2	2-½	3	4	5	6
A OUTSIDE DIA., in.[A]	.405	.540	.675	.840	1.050	1.315	1.660	1.900	2.375	2.875	3.500	4.500	5.563	6.625
B THICKNESS:, in.[A]														
(STANDARD)	.068	.088	.091	.109	.113	.133	.140	.145	.154	.203	.216	.237	.258	.280
(EXTRA STRONG)	.095	.119	.126	.147	.154	.179	.191	.200	.218	.276	.300	.337	.375	.432
L LENGTH ±1⁄16 IN.[A]	DASH NUMBERS													
¾	[A]1													
⅞		[B]25												
1			[B]49											
1-⅛				[B]73										
1-⅜					[B]97									
1-½	[C]6	[C]29	[C]52	[C]75		[B]121								
1-⅝							[B]145							
1-¾							[B]169							
2	9	32	55	78	[C]101	[C]124			[B]193					
2-½	10	33	56	79	102	125	[C]148	[C]171	[C]194	[B]217				
3	11	34	57	80	102	126	149	172	195	[C]218	[C]241			
3-½	12	35	58	81	104	127	150	173	196	219	242			
4	13	36	59	82	105	128	151	174	197	220	243			
4-½	14	37	60	83	106	129	152	175	198	221	244		[C]290	[C]313
5	15	38	61	84	107	130	153	176	199	222	245			
5-½	16	39	62	85	108	131	154	177	200	223	246			
6	17	40	63	86	109	132	155	178	201	224	247	270		316
7	18	41	64	87	110	133	156	179	202	225	248			
8	19	42	65	88	111	134	157	180	203	226	249			
9	20	43	66	89	112	135	158	181	204	227	250			
10	21	44	67	90	113	136	159	182	205	228	251			
11	22	45	68	91	114	137	160	183	206	229	252			
12	23	46	69	92	115	138	161	184	207	230	253			

Notes:

[A] 1 in. = 25.4 mm
[B] Close type nipples
[C] Short (shoulder) type nipples



[a] Close type   [b] Short (shoulder) type   Long type

FIG. 1 Standard and Extra Strong Steel Pipe Nipples

5.2 *Inspection*—The samples shall be inspected to determine their conformance with the dimensional requirements, including thread dimensions and finish of this specification.

5.3 *Gaging Techniques for Male Threads*:

5.3.1 An NPT working ring gage, in accordance with ANSI B1.20.1, shall be turned hand tight on the nipple threads. The gage shall be tapped or rapped against a solid surface and the gage again turned hand tight into the thread. Hand tight means turning the gage until moderate resistance is encountered; no excessive force shall be used. After the second tightening operation, the end of the thread should be flush to the gage face, plus or minus one turn.

5.3.2 The usual technique for tapping or rapping the gage is to swing the end of the fitting with the ring gage attached through an arc of approximately 4 to 6 in. (100 to 150 mm) to allow the gage to strike against a solid metal surface. This tapping procedure is used to eliminate any binding due to slight nicks or foreign matter in the threads.

NOTE 2—Any mechanical device that simulates the gage tapping or rapping to achieve the same results is also permitted.

5.4 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the nipples ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the nipples are being furnished in accordance with this specification. Inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

6. Rejection

6.1 Each nipple that fails to meet the requirement of this specification shall be rejected, and the manufacturer notified.

7. Certification

7.1 When requested at the time the order is placed, the manufacturer shall provide certification that the nipples comply to all the requirements of this specification.

7.2 The nipple manufacturer shall maintain a record on pipe mill test report certifications.

8. Identification and Packaging

8.1 Individual nipples are not normally identified. Packaged nipples shall have their containers legibly marked to show the brand or name of manufacturer, size, length, quantity, method of pipe manufacture, type and grade of material (if other than carbon steel), ASTM A 733, and finish.

8.2 At manufacturer's option, large size, extra long nipples, and odd lots are bagged or bundled with tags identifying the product in accordance with 8.1.

9. Keywords

9.1 carbon steel fittings; pipe fittings; pipe nipples; stainless steel fittings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U.S. Government.

S1.1 *Part Numbering System*—This supplement provides a part numbering system for identification of standard items for government use of Specification A 733. (See also Table 3 and Fig. 1).

NOTE S1.1—The government encourages the general use of this part numbering system to achieve maximum parts standardization.

S1.2 The part number consists of the document identifier followed by the code for the weight of material (standard or extra strong), a dash, dash number, material code, method of manufacture code, and finish code (see example).

S1.2.1 *Example*—Part Identifying Number "A733S–198CFB" is constructed as follows in Fig. S1:

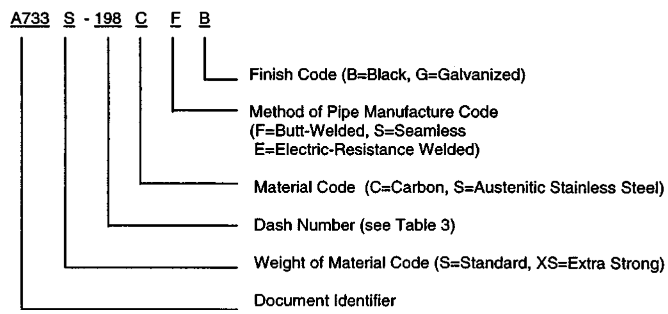


FIG. S1 Construction of Part Identifying Number

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last edition (A 733-01) that may impact the use of this standards (approved April 2003).

(1) 4.1was revised to permit the use of NDE-tested pipe.

Designation: A 727/A 727M – 02 (Reapproved 2007)

Standard Specification for Carbon Steel Forgings for Piping Components with Inherent Notch Toughness[1]

This standard is issued under the fixed designation A 727/A 727M; 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 forged carbon steel piping components intended primarily for service in pressure piping systems from −20 to +650 °F [−30 to +345 °C] where inherent notch toughness is desired, but where notch toughness testing is not required. Included are forged or ring-rolled flanges, forged fittings, and valves made to specified dimensions, or to dimensional standards such as the ASME and API specifications referenced in Section 2.

1.2 This specification is limited to forgings with maximum finished section thicknesses no larger than 2 in. [51 mm].

1.3 It shall be the responsibility of the purchaser to determine whether material meeting the requirements of this specification is satisfactory for the service application.

1.4 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified by the purchaser in the order.

NOTE 1—There are no provisions for impact testing in this specification. When impact testing is required, refer to Specification A 350/A 350M.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 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.

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A 961/A 961M, the following list of standards apply to this specification.

2.2 *ASTM Standards:* [3]

A 350/A 350M Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 788/A 788M Specification for Steel Forgings, General Requirements

A 961/A 961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[4]

2.3 *ASME Boiler and Pressure Vessel Codes:*[5]

Section II, Material Specifications, Part C

SFA 5.5 Low-Alloy Steel Covered Arc-Welding Electrodes

B 16.5 Steel Pipe Flanges and Flanged Fittings

B 16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves

B 16.11 Forged Steel Fittings, Socket-Welding and Threaded

B 16.30 Unfired Pressure Vessel Flange Dimensions

2.4 *API Standards:*[6]

600 Steel Gate Valves with Flanged or Butt-Welding Ends

602 Compact Design Carbon Steel Gate Valves for Refinery Use

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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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved March 1, 2007. Published April 2007. Originally approved in 1976. Last previous edition approved in 2002 as A 727/A 727M – 02.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-727 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] Withdrawn.

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[6] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://api-ec.api.org.

605 Large Diameter Carbon Steel Flanges

2.5 *MSS Standard:*[7]

MSS SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions

3. General Requirements and Ordering Information

3.1 Product furnished to this specification shall conform to the requirements of Specification A 961/A 961M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 961/A 961M constitutes nonconformance with this specification. In case of a conflict between the requirements of this specification and Specification A 961/A 961M, this specification shall prevail.

3.2 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the following:

3.2.1 Additional requirements (see 15.1 and 15.2).

4. Materials and Manufacture

4.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace, and shall be fully killed, fine-grain practice.

4.2 Forgings shall be manufactured from ingots, blooms, billets, slabs, or bars. These items shall be forged, rolled, or strandcast.

4.3 A sufficient discard shall be made from the ingot to secure freedom from injurious piping and undue segregation.

4.4 The finished product shall be a forging as defined by the Terminology section of Specification A 788/A 788M.

5. Heat Treatment

5.1 Following plastic working, the forging manufacturer shall heat treat the forgings by normalizing, or normalizing and tempering, or quenching and tempering.

5.1.1 *Normalizing*—The procedure for normalizing shall consist of uniformly heating the forgings to a temperature between 1550 and 1700 °F [845 and 925 °C], holding a sufficient time to attain uniform temperature throughout, and cooling in still air. The forging shall be at a temperature below 1000 °F [540 °C] before heating for normalizing.

5.1.2 *Quenching*—The procedure for quenching shall consist of uniformly heating the forging to a temperature between 1550 and 1700 °F [845 and 925 °C], holding a sufficient time to attain uniform temperature throughout, and quenching into a suitable liquid medium. The forging shall be at a temperature below 1000 °F [540 °C] before heating for quenching.

5.1.3 *Tempering*—The procedure for tempering shall consist of reheating the forging subsequent to normalizing or quenching to a temperature of at least 1100 °F [595 °C], but not above the lower transformation temperature, for 30 min/in. [30 min/25 mm] of maximum section thickness, with minimum holding time at tempering temperature not less than 30 min.

6. Chemical Composition

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

6.2 Steels to which lead has been added shall not be used.

7. *Mechanical Requirements* Mechanical Requirements

7.1 *Tension Tests*:

7.1.1 *Requirements*—The material shall conform to requirements for tensile properties prescribed in Table 2.

7.1.1.1 The test specimen shall be obtained from a rough or finished production forging, or prolongation thereof, or it may be obtained from separately forged test blanks from the same heat of steel as the production forging. The test blank shall be reduced by forging in a manner similar to that for the products represented, shall receive approximately the same hot working and reduction, be of the same nominal thickness, and receive the same heat treatment as the finished products represented. The test material shall be treated in the same furnace at the same time as the forging it represents, subject to the requirements of 7.1.2.1.

7.1.2 *Number of Tests*—One tension test at room temperature shall be made for each nominal wall thickness ± ¼ in. [± 6 mm] from each heat in each heat treatment charge.

7.1.2.1 If heat treatment is performed in either a continuous or a batch-type furnace controlled within ± 25 °F [± 14 °C] of the required heat-treatment temperature, and equipped with

TABLE 1 Chemical Requirements

Elements	Composition, %
Carbon	
Heat Analysis	0.25 max
Product Analysis	0.28 max
Manganese	
Heat Analysis	0.90 to 1.35
Product Analysis	0.84 to 1.41
Phosphorus	
Heat Analysis	0.035 max
Product Analysis	0.043 max
Sulfur	
Heat Analysis	0.025 max
Product Analysis	0.033 max
Silicon	
Heat Analysis	0.15 to 0.30
Product Analysis	0.13 to 0.32
Nickel	
Heat Analysis	0.40[A]
Product Analysis	0.43
Chromium	
Heat Analysis	0.30[A,B]
Product Analysis	0.34
Molybdenum	
Heat Analysis	0.12[A,B]
Product Analysis	0.13
Copper	
Heat Analysis	0.40[A]
Product Analysis	0.43
Columbium (Nb)	
Heat Analysis	0.02
Product Analysis	0.03
Vanadium	
Heat Analysis	0.05
Product Analysis	0.055

[A] The sum of copper, nickel, chromium and molybdenum shall not exceed 1.00 % on heat analysis.

[B] The sum of chromium and molybdenum shall not exceed 0.32 % on heat analysis.

[7] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602, http://www.mss-hq.com.

TABLE 2 Tensile Requirements

Tensile strength, ksi [MPa]	60.0 to 85.0 [415 to 585]
Yield strength, min, ksi [MPa][A]	36.0 [250]
Elongation in 2 in. or 50 mm, min, %	22
Reduction of area, min, %	30

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

recording pyrometers so that complete records of heat treatment are available and if the same heat treating cycles are used on the forgings represented by the tension test, then one tension test per nominal wall thickness ± ¼ in. [± 6 mm] from each heat shall be required, instead of one tension test per nominal wall thickness from each heat in each heat-treatment charge.

7.1.3 *Test Locations and Orientations*—The test specimen shall be removed from the midwall of the heaviest section of the forging or test blank.

7.1.3.1 The test specimen shall have its longitudinal axis located parallel to the direction of major working of the forging or test blank, except for flanges and rings the test specimen shall be in the tangential direction.

7.1.4 *Test Method*—Testing shall be performed in accordance with Test Methods and Definitions A 370 using the largest feasible of the round specimens. The gage length for measuring elongation shall be four times the diameter of the test section.

7.2 *Hardness Test*:

7.2.1 *Requirements*—If the production forgings are liquid-quenched and tempered, hardness of the forgings shall not exceed 187 HB after heat treatment. The purchaser may verify that the requirement has been met by testing at any location on the forgings provided such testing does not render the forgings useless.

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made from samples taken preferably during the pouring of the heat. The results shall conform to Table 1.

9. Product Analysis

9.1 A product analysis may be made by the purchaser on samples taken in accordance with Practice E 59. The results shall conform to Table 1.

10. Hydrostatic Test

10.1 Forgings manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the finished forging. Such tests shall be conducted by the forging manufacturer only when Supplementary Requirement S8 in Specification A 961/A 961M is specified.

11. Rework and Retreatment

11.1 If the results of mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings represented, and shall retest to the applicable requirements.

11.2 Individually tested forgings meeting all requirements shall be acceptable.

12. Repair by Welding

12.1 Repair of defects by welding shall be permitted at the discretion of the forging manufacturer.

12.2 Repair by welding shall be made using welding procedures and welders qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. When forgings are heat treated after repair welding, the qualification test plates shall be subjected to the same heat treatment. The mechanical properties of the qualification test plates shall conform to Section 7.

12.3 Only electrode classifications with the -A1 designator shall be used (for example, E71T1-A1). SMAW, GMAW, FCAW or GTAW may be used. The GMAW process is limited to either the spray transfer or pulsed arc process. The FCAW process is limited to repair of carbon or carbon-molybdenum base materials only. Electrodes shall conform to the applicable AWS A5 electrode specification.

12.4 Forgings repair welded in the normalized, normalized and tempered, or the quenched and tempered conditions shall be stress-relieved after repair welding at 1100 °F [595 °C] minimum, but not higher than the temperature previously used for tempering the base metal of the same forging, or shall be reheat treated in accordance with Section 5.

13. Inspection

13.1 All tests and inspections shall be made at the place of manufacture, unless otherwise agreed, except for product analysis (see 9.1).

14. Rejection and Rehearing

14.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

15. Certification

15.1 For forgings made to specified dimensions, when agreed to by the purchaser, and for forgings made to dimensional standards, application of identification marks as required in Section 16 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification.

15.2 When test reports are required, they shall include certification that all requirements of this specification have been met. The reports shall show the results of all required tests, the heat number or manufacturer's heat identification, a description of the heat treatment used, and shall be traceable to the forging represented. The specification designation included on test reports shall include year of issue and revision letter, if any.

16. Product Marking

16.1 Identification marks consisting of the specification designation, manufacturer's name or symbol, (Note 2) the heat number or manufacturer's heat identification, size, and service rating, if applicable, shall be permanently placed on each forging in a position that will not affect the usefulness of the forging. When size does not permit complete marking, identification marks may be omitted in the sequence specified in

SP-25, except that the word "steel" shall not be substituted for the specification designation. The specification number marked on the forgings need not include specification year of issue and revision letter.

NOTE 2—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

16.1.1 If the forgings have been quenched and tempered the letters "QT" shall be stamped on the forgings following the Specification designation.

16.1.2 Forgings repaired by welding shall be marked with the letter "W" following the specification designation.

16.2 When test reports are required, additional marks shall be used as necessary to identify the part with the test report.

16.3 *Bar Coding*—In addition to the requirements in 16.1 and 16.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

17. Keywords

17.1 carbon equivalent; pipe fittings; steel; piping applications; pressure containing parts; steel flanges; steel forgings; carbon; steel valves; temperature service applications; low

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification.

S1. Carbon Equivalent

S1.1 The maximum carbon equivalent, based on heat analysis shall be 0.45 for forgings with a maximum section thickness of 2 in. or less, and 0.46 for forgings with a maximum section thickness of greater than 2 in.

S1.2 Determine the carbon equivalent (CE) as follows:

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

S1.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

Designation: A 714 – 99 (Reapproved 2003)

Standard Specification for High-Strength Low-Alloy Welded and Seamless Steel Pipe[1]

This standard is issued under the fixed designation A 714; 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 covers seamless and welded high-strength low-alloy steel pipe NPS ½ to NPS 26, inclusive. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification. This material is intended for pressure piping service, and other general purposes, where savings in weight or added durability are important.

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."

NOTE 2—A comprehensive listing of standardized pipe dimensions is contained in ANSI Standard B36.10.

1.2 *Class*—These high-strength low-alloy steels have enhanced resistance to general atmospheric corrosion by weathering as commonly encountered in rural, urban, marine, and industrial environments. They are supplied in two classes: Class 2, having corrosion resistance equivalent to that of carbon steel with copper (0.20 minimum Cu); and Class 4, having corrosion resistance substantially better than that of Class 2 (Note 3). Class 4 steels when properly exposed to the atmosphere can be used bare (unpainted) for many applications.

NOTE 3—For methods of estimating the atmospheric corrosion resistance of low alloy steels see Guide G 101 or actual data.

1.3 *Type*—Pipe may be furnished in the following types of manufacturing processes:

Type F—Furnace-butt welded, continuous welded,
Type E—Electric-resistance welded, and
Type S—Seamless.

1.3.1 Pipe ordered under this specification is suitable for welding.

1.3.2 Type E pipe may be furnished either nonexpanded or cold-expanded at the option of the manufacturer.

1.3.3 Types F, E, and S pipe are commonly furnished in nonheat-treated condition. Type S pipe may be furnished in normalized (or other) heat-treated condition, when so specified.

1.3.4 Types F, E, and S pipe in single random lengths may be furnished with hot-dipped galvanized coating of zinc, subject to inquiry to the producer.

1.3.5 Couplings, when furnished, shall be of the same class, heat-treated condition, and grade of material as the pipe ordered.

1.4 *Grade*—This specification designates eight grades of steel composition as listed in Table 1 and corresponding tensile requirements for the grades as listed in Table 2.

1.4.1 For Class 2 pipe, Grade I, II, or III shall be specified, and copper-bearing steel is required as specified in Table 1.

1.4.2 For Class 4 pipe, Grade IV, V, VI, VII, or VIII shall be specified. Alternatively, for Class 4, Type S, and Type E pipe, a steel composition corresponding to a grade listed in Table 1 of Specification A 588/A 588M may be specified, subject to negotiation.

1.5 When Class 4 pipe is joined by welding or is used in welded construction, the user is cautioned that the selection of welding procedure and resultant composition of fused metal should be suitable for Class 4 material and the intended service.

1.6 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
A 90 Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 588/A 588M Specification for High Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4-in. [100-mm] Thick
A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Mar. 10, 1999. Published May 1999. Originally approved in 1975. Last previous edition approved in 1996 as A 714 – 96.

[2] 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.

TABLE 1 Chemical Requirements

Element	Composition, %							
	Grade I		Grade II		Grade III		Grade IV	
	Heat	Product	Heat	Product	Heat	Product	Heat	Product
Carbon, max	0.22	0.26	0.22	0.26	0.23	0.27	0.10	0.13
Manganese	1.25 max	1.30 max	0.85 to 1.25	1.30 max	1.35 max	1.40 max	0.60 max	0.65 max
Phosphorus	...	...	0.04 max	0.05 max	0.04 max	0.05 max	0.03 to 0.08	[A]
Sulfur, max	0.05	0.063	0.05	0.063	0.05	0.06	0.05	0.06
Silicon	...	...	0.30 max	0.33 max	0.30 max	0.35 max	...	...
Copper	0.20 min	0.18 min	0.20 min	0.18 min	0.20 min	0.18 min	0.25 to 0.45	0.22 to 0.48
Vanadium	...	...	0.02 min	0.01 min	0.02[B] min	0.01 min	...	...
Nickel	...	...	...	...	...	...	0.20 to 0.50	0.17 to 0.53
Chromium	...	...	...	...	...	...	0.80 to 1.20	0.74 to 1.26
Molybdenum	...	...	...	...	...	...	...	...

Element	Composition, %							
	Grade V		Grade VI		Grade VII		Grade VIII	
	Heat	Product	Heat	Product	Heat	Product	Heat	Product
Carbon, max	0.16	0.20	0.15	0.18	0.12	0.15	0.19	0.23
Manganese	0.40 to 1.01	0.35 to 1.06	0.50 to 1.00	0.45 to 1.05	0.20 to 0.50	0.17 to 0.53	0.80 to 1.25	0.74 to 1.31
Phosphorus	0.035 max	0.045 max	0.035 max	0.045 max	0.07 to 0.15	[A]	0.04 max	0.05 max
Sulfur, max	0.040	0.050	0.045	0.055	0.05	0.06	0.05	0.06
Silicon	...	...	...	...	0.25 to 0.75	0.20 to 0.80	0.30 to 0.65	0.25 to 0.70
Copper	0.80 min	0.75 to 1.25	0.30 to 1.00	0.27 to 1.03	0.25 to 0.55	0.22 to 0.58	0.25 to 0.40	0.22 to 0.43
Vanadium	...	...	...	...	...	...	0.02 to 0.10	0.01 to 0.11
Nickel	1.65 min	1.60 to 2.24	0.40 to 1.10	0.35 to 1.15	0.65 max	0.68 max	0.40 max	0.43 max
Chromium	...	...	0.30 max	0.33 max	0.30 to 1.25	0.24 to 1.31	0.40 to 0.65	0.36 to 0.69
Molybdenum	...	...	0.10 to 0.20	0.09 to 0.21	...	...	...	...

[A] Because of the degree to which phosphorus segregates, product analysis for this element is not technologically appropriate for rephosphorized steels unless misapplication is clearly indicated.
[B] For Grade III, columbium may be used in conformance with the following limits: 0.005 % min (heat) and 0.004 % min (product).

TABLE 2 Tensile Requirements

	Class 2 Pipe			Class 4 Pipe					
	Grade I	Grade II	Grade III	Grade IV	Grade V, Type F	Grade V, Type E and S	Grade VI, Type E and S	Grade VII,[A] Type E and S	Grade VIII, Type E and S
Tensile strength, min, psi (MPa)	70 000 (485)	70 000 (485)	65 000 (450)	58 000 (400)	55 000 (380)	65 000 (450)	65 000 (450)	65 000 (450)	70 000 (485)
Yield strength, min, psi (MPa)	50 000 (345)	50 000 (345)	50 000 (345)	36 000 (250)	40 000 (275)	46 000 (315)	46 000 (315)	45 000 (310)	50 000 (345)
Elongation in 2 in. (50.8 mm) min, %	22	22	20	[B,C]	[B,C]	[B,C]	[B,C]	22	21
Elongation in 8 in. (203.2 mm) min, %	19	18	18	. . .	. . .	. . .	. . .	. . .	. . .

[A] Not available in wall thicknesses over ½ in.
[B] The minimum elongation in 2 in. (50.8 mm) shall be determined by the following equation:

$$e = 625\ 000(A^{0.2}/U^{0.9})$$

where:

e = *minimum elongation in 2 in. (50.8 mm), rounded to nearest 0.5 %,*
A = *cross-sectional area of the tension test specimen in square inches, based on specified outside diameter or nominal specimen width and specified wall thickness rounded to the nearest 0.01 in.*^{2} *If the area thus calculated is greater than 0.75 in.*^{2}*, then the value of 0.75 in.*^{2} *shall be used, and*
U = *specified tensile strength, psi.*

[C] See Table X1.1 for minimum elongation values for various size tension specimens and grades.

B 6 Specification for Zinc
G 101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels

2.2 *ANSI Standard:*

B36.10 Welded and Seamless Wrought Steel Pipe[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *defect*, *n*—any imperfection of sufficient size or magnitude to be cause for rejection.

3.1.2 *imperfection*, *n*—any discontinuity or irregularity found in the pipe.

4. Ordering Information

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

4.1.1 Quantity (feet, or metres, or number of lengths),

4.1.2 Name of material (steel pipe),

4.1.3 Class of pipe (Class 2 or Class 4, see 1.2),

4.1.4 Method of manufacture or Type of pipe (Types F, E, or S, see 1.3),

4.1.5 Grade (see 1.4),

4.1.6 Heat treatment, when required (see 1.3.3),

4.1.7 Surface finish (bare, oiled, coated, or galvanized),

4.1.8 Size (either NPS and weight class or schedule number, or both; or outside diameter and nominal wall thickness),

4.1.9 Length (specific or random, see Section 14),

4.1.10 End finish (plain or threaded, see Section 15),

4.1.11 Skelp for tension tests, if permitted (see 11.2),

4.1.12 Couplings, if threaded; no couplings, if not desired; couplings power-tight, if so desired,

4.1.13 Specification number,

4.1.14 End use of material, and

4.1.15 Special requirements.

5. Materials and Manufacture

5.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

5.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

5.3 The pipe shall be made by the seamless, furnace-buttwelded (continuous-welded), or electric resistance-welded process.

6. Chemical Composition

6.1 When subjected to the heat and product analysis, respectively, the steel shall conform to the requirements prescribed in Table 1. Chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

6.2 For Grade I, the choice and use of alloying elements, combined with carbon, manganese, sulfur, and copper within the limits prescribed in Table 1 to give the mechanical properties prescribed in Table 2, shall be made by the manufacturer and included and reported in the heat analysis for information purposes only to identify the type of steel applied. For Class 4 material, the atmospheric corrosion–resistance index, calculated on the basis of the chemical composition of the steel as described in Guide G 101, shall be 6.0 or higher.

NOTE 4—The user is cautioned that the Guide G 101 predictive equation for calculation of an atmospheric corrosion–resistance index has been verified only for the composition limits stated in that guide. It is not applicable, for example, for Specification A 714 Grade V because the copper and nickel contents of this grade are greater than the limits specified in Guide G 101.

6.3 *Heat Analysis*—An analysis of each heat of open-hearth, basic-oxygen or electric-furnace steel shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall conform to the requirements specified in Table 1 for heat analysis.

6.4 *Product Analysis*:

6.4.1 An analysis may be made by the purchaser from finished pipe manufactured in accordance with this specification, or an analysis may be made from flat-rolled stock from which the welded pipe is manufactured. When product analyses are made, two sample lengths from each lot of 500 lengths or fraction thereof shall be selected. The chemical composition thus determined shall conform to the requirements specified in Table 1 for product analysis.

6.4.2 In the event that the chemical composition of one of the sample lengths does not conform to the requirements shown in Table 1 for product analysis, an analysis shall be made on two additional lengths selected from the same lot, each of which shall conform to the requirements specified in Table 1 for product analysis, or the lot is subject to rejection.

7. Tensile Requirements

7.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2 for the grade of Class 2 or Class 4 pipe specified.

7.2 The yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen or to a total extension of 0.5 % of the gage length under load shall be determined.

7.3 The test specimen taken across the weld of welded pipe shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe ordered. This test will not be required for pipe under NPS 8.

7.4 Transverse tension test specimens for electric-welded pipe NPS 8 and larger shall be taken opposite the weld. All transverse test specimens shall be approximately 1½ in. (38.1 mm) wide in the gage length, and shall represent the full wall thickness of the pipe from which the specimen was cut.

8. Bending Requirements

8.1 For pipe NPS 2 and under, a sufficient length of pipe shall withstand being bent cold through 90° around a cylindrical mandrel, the diameter of which is twelve times the nominal diameter of the pipe, without developing cracks at any portion and without opening the weld. Double-extra-strong pipe need not be subjected to the bend test.

9. Flattening Test

9.1 The flattening test shall be made on pipe over NPS 2 with wall thicknesses extra strong and lighter.

[3] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

9.2 *Seamless Pipe*:

9.2.1 For seamless pipe a section not less than 2 ½ in. (63.5 mm) in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, no cracks or breaks on the inside or outside or end surfaces, except as provided for in 9.7, shall occur until the distance between the plates is less than the value of H calculated as follows:

$$H\frac{(1 + e)t}{(e + t / D)}$$

where:

H = distance between flattening plates, in. or mm,
e = deformation per unit length (constant for a given grade of steel, 0.07),
t = specified wall thickness, in. or mm, and
D = specified outside diameter, in. or mm.

9.2.2 During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material that is revealed during the entire flattening test shall be cause for rejection.

9.3 *Electric-Resistance-Welded Pipe*— A specimen at least 4 in. (101.6 mm) in length shall be flattened cold between parallel plates in three steps with the weld located either 0° or 90° from the line of direction of force as required in 9.3.1. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than two thirds of the original outside diameter of the pipe. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than one third of the original outside diameter of the pipe but is not less than five times the wall thickness of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

9.3.1 For pipe produced in single lengths, the flattening test specified in 9.3 shall be made on both crop ends cut from each length of pipe. The tests from each end shall be made alternately with the weld at 0° and at 90° from the line of direction of force. For pipe produced in multiple lengths, the flattening test shall be made on crop ends representing the front and back of each coil with the weld at 90° from the line of direction of force, and on two intermediate rings representing each coil with the weld 0° from the line of direction of force.

9.4 *Butt-Welded Pipe*—For butt-welded pipe, a specimen not less than 4 in. (101.6 mm) in length shall be flattened cold between parallel plates in three steps. The weld shall be located 90° from the line of direction of force. During the first step, which is a test for quality of the weld, no cracks or breaks on the inside, outside, or end surfaces shall occur until the distance between the plates is less than 0.85 times the original outside diameter for butt-welded pipe. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside, outside, or end surfaces, except as provided for in 9.7, shall occur until the distance between the plates is less than 60 % of the original outside diameter for butt-welded pipe. During the third step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

9.5 Surface imperfections in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements in Section 17.

9.6 Superficial ruptures as a result of surface imperfections shall not be cause for rejection.

9.7 When low D-to-t ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than ten.

10. Hydrostatic Test

10.1 Each length of Type F, E, or S pipe shall be tested at the mill to the hydrostatic pressures prescribed for butt weld or Grade B pipe as specified in Table X2 (for plain end pipe) or Table X3 (for threaded-and-coupled pipe) of Specification A 53/A 53M. The hydrostatic test may be applied, at the discretion of the manufacturer, on pipe with plain ends, with threads only, or with threads and couplings and may be applied in single lengths or multiple lengths.

10.2 The maximum specified hydrostatic test pressure shall not exceed 2500 psi (17.2 MPa) for NPS 3 and under, or 2800 psi (19.3 MPa) for all over NPS 3. The hydrostatic pressure shall be maintained for not less than 5 s for all sizes of seamless and welded pipe.

11. Test Methods

11.1 The test specimens and the tests required by this specification shall conform to those described in the latest issue of Test Methods and Definitions A 370.

11.2 The longitudinal tension test specimen shall be taken from the end of the pipe or, by agreement between the manufacturer and the purchaser, may be taken from the skelp, at a point approximately 90° from the weld, and shall not be flattened between gage marks. The sides of each specimen shall be parallel between gage marks. If desired, the tension test may be made on the full section of pipe. When impracticable to pull a test specimen in full thickness, the standard 2-in. (50.8-mm) gage length tension test specimen shown in Fig. 6 of Test Methods and Definitions A 370 may be used.

11.3 Transverse weld test specimens from electric-welded pipe shall be taken with the weld at the center of the specimen. All transverse test specimens shall be approximately 1½ in. (38.1 mm) wide in the gage length and shall represent the full wall thickness of the pipe from which the specimen was cut.

11.4 Test specimens for the bend and flattening tests shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except when made on crop ends taken with welded pipe.

11.5 All specimens shall be tested at room temperature.

12. Dimensions and Weights

12.1 The dimensions and weights furnished under this specification are included in the ANSI Standard B36.10.

13. Permissible Variations in Weights and Dimensions

13.1 *Weight*——The weight of the pipe shall not vary by more than the following amounts:

Extra-strong and lighter wall thickness	±5 %
Heavier than extra-strong wall thickness	±10 %

NOTE 5—The weight tolerance of ±5 % or ±10 %, as the case may be, is determined from the weights of the customary lifts of pipe as produced for shipment by the mill, divided by the number of feet of pipe in the lift. On pipe sizes over NPS 4 where individual lengths may be weighed, the weight tolerance is applicable to the individual length.

13.2 *Diameter*—For pipe NPS 1 ½ and under, the outside diameter at any point shall not vary more than 1⁄64 in. (0.40 mm) over nor more than 1⁄32 in. (0.79 mm) under the standard specified. For pipe NPS 2 and over, the outside diameter shall not vary more than ±1 % from the standard specified.

13.3 *Thickness*— The minimum wall thickness at any point shall be not more than 12.5 % under the nominal wall thickness specified.

14. Lengths

14.1 Unless otherwise specified, pipe lengths shall be in accordance with the following regular practice:

14.1.1 Pipe of weights lighter than extra-strong shall be in single-random lengths of 16 to 22 ft (4.88 to 6.71 m), but not more than 5 % of the total number of threaded lengths may be jointers, which are two pieces coupled together. When ordered with plain ends, 5 % may be in lengths of 12 to 16 ft (3.66 to 4.88 m).

14.1.2 Pipe of extra-strong and heavier weights shall be in random lengths of 12 to 22 ft (3.66 to 6.71 m). Five percent may be in lengths of 6 to 12 ft (1.83 to 3.66 m).

14.1.3 When extra-strong or lighter pipe is ordered in double-random lengths, the minimum lengths shall be not less than 22 ft (6.71 m), with a minimum average for the order of 35 ft (10.67 m).

14.1.4 When lengths longer than single random are required for wall thicknesses heavier than extra-strong, the length shall be subject to negotiation.

15. End Finish

15.1 *Plain End*— Pipe sizes and weights ordered with plain end shall be furnished to the following regular practices, unless otherwise specified:

15.1.1 Pipe of standard or extra-strong weights, or in wall thicknesses 0.500 in. (12.7 mm) or less, other than double-extra-strong pipe, shall be plain end beveled.

15.1.2 Pipe with wall thicknesses over 0.500 in. (12.7 mm), and all double-extra-strong pipe, shall be plain end cut square.

15.2 *Threaded and Coupled Pipe*—The threads of pipe and couplings on pipe ordered with threads, or with threads and couplings, shall be in accordance with the requirements of threads and couplings of Specification A 53/A 53M.

16. Galvanized Pipe

16.1 Galvanized pipe ordered under this specification shall be coated with zinc inside and outside by the hot-dip process. The zinc used for the coating shall be any grade of zinc conforming to Specification B 6.

16.2 *Weight of Coating*—The weight of zinc coating shall be not less than 1.8 oz/ft^2(0.55 kg/m^2) as determined from the average results of the two specimens taken for test in the manner prescribed in 16.5 and not less than 1.6 oz/ft^2(0.49 kg/m^2) for either of these specimens. The weight of coating expressed in ounces per square foot (or kilograms per square metre) shall be calculated by dividing the total weight of zinc, inside plus outside, by the total area, inside plus outside, of the surface coated.

16.3 *Weight of Coating Test*—The weight of zinc coating shall be determined by a stripping test in accordance with Test Method A 90. The total zinc on each specimen shall be determined in a single stripping operation.

16.4 *Test Specimens*—Test specimens for determination of weight of coating shall be cut approximately 4 in. (101.6 mm) in length.

16.5 *Number of Tests*—Two test specimens for the determination of weight of coating shall be taken, one from each end of one length of galvanized pipe selected at random from each lot of 500 lengths or fraction thereof, of each size.

16.6 *Retests*—If the weight of coating of any lot does not conform to the requirements specified in 16.2, retests of two additional pipes from the same lot shall be made, each of which shall conform to the requirements specified.

16.7 When pipe ordered under this specification is to be galvanized, the tension, flattening, and bend tests shall be made on the base material before galvanizing. When specified, results of the mechanical tests on the base material shall be reported to the purchaser. If impracticable to make the mechanical tests on the base material before galvanizing, such tests may be made on galvanized samples, and any flaking or cracking of the zinc coating shall not be considered cause for rejection. When galvanized pipe is bent or otherwise fabricated to a degree which causes the zinc coating to stretch or compress beyond the limit of elasticity, some flaking of the coating may occur.

17. Workmanship, Finish, and Appearance

17.1 The finished pipe shall be reasonably straight and free of defects. Any imperfection that exceeds 12½ % of the nominal wall thickness, or violates the minimum wall, shall be considered a defect. The pipe ends shall be free of burrs.

17.2 The zinc coating on galvanized pipe shall be free of voids or excessive roughness.

18. Number of Tests

18.1 One of each of the tests specified in Sections 7, 8, and 9, except 9.3.1 shall be made on one length of pipe from each lot of 500 lengths, or fraction thereof, of each size. A length is defined as the length as ordered, except that in the case of orders for cut lengths shorter than single random, the term lot shall apply to the lengths as rolled, prior to cutting to the required short lengths.

18.2 The number of flattening tests for electric-resistance-welded pipe shall be in accordance with 9.3.1.

18.3 Each length of pipe shall be subjected to the hydrostatic test specified in Section 10.

19. Retests

19.1 If the results of the mechanical tests of any lot do not conform to the requirements specified in Sections 7, 8, and 9, retests may be made on additional pipe of double the original number from the same lot, each of which shall conform to the requirements specified.

19.2 If any section of the pipe fails to comply with the requirements of 9.3 for pipe produced in single lengths, other sections may be cut from the same end of the same length until satisfactory tests are obtained, except that the finished pipe shall not be shorter than 80 % of its length after the original cropping; otherwise the length shall be rejected. For pipe produced in multiple lengths, retests may be cut from each end of each individual length in the multiple. Such tests shall be made with the weld alternately 0° and 90° from the line of direction of force.

20. Inspection

20.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified and shall be so conducted as not to interfere unnecessarily with the operation of the works.

21. Rejection

21.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined herein, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

21.2 Pipe found in fabrication or in installation to be unsuitable for the intended end use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation conditions, or both, involved. Disposition shall be a matter for agreement.

22. Product Marking

22.1 Each length of pipe shall be legibly marked by rolling, stamping, or stenciling to show the following:

22.1.1 Name or brand of the manufacturer,

22.1.2 Class of pipe (Class 2 or Class 4),

22.1.3 Grade of pipe (I, II, III, IV, V, VI, VII, or VIII),

22.1.4 Type of pipe (Type F, E, or S),

22.1.5 Weight designation, for example, XS for extra strong, or XXS for double extra strong, or the nominal weight per foot when other than STD, XS, or XXS weights are ordered and produced,

22.1.6 Specification number, and

22.1.7 Length of pipe.

22.2 For pipe NPS 1½ and smaller which is bundled, this information may be marked on a tag securely attached to each bundle.

23. Packaging, Marking, and Loading

23.1 When specified on the purchase order, packaging, marking, and loading or shipment shall be in accordance with the procedures of Practices A 700.

23.2 *Bar Coding*—In addition to the requirements in 23.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

APPENDIX

(Nonmandatory Information)

X1. ELONGATION VALUES

X1.1 —Tabulated in Table X1.1 are the minimum elongation values calculated by the equation given in Table 2.

TABLE X1.1 Elongation Values

Area,[A] in.²	Tension Test Specimen				Elongation in 2 in., min, %			
	Specified Wall Thickness, in.[B]				Specified Tensile Strength, psi			
	½-in. Specimen	¾-in. Specimen	1-in. Specimen	1½-in. Specimen	55 000	58 000	65 000	70 000
0.75	1.491 1.509	0.994 1.006	0.746 0.754	0.497 0.503	32.0	30.5	27.5	25.5
0.74	1.470 1.490	0.980 0.993	0.735 0.745	0.490 0.496	32.0	30.5	27.5	25.5
0.73	1.451 1.469	0.967 0.979	0.726 0.734	0.484 0.489	32.0	30.5	27.5	25.5
0.72	1.430 1.450	0.954 0.966	0.715 0.725	0.477 0.483	31.5	30.0	27.5	25.5

TABLE X1.1 *Continued*

Area,[A] in.^{2}	Tension Test Specimen				Elongation in 2 in., min, %			
	Specified Wall Thickness, in.[B]				Specified Tensile Strength, psi			
	½-in. Specimen	¾-in. Specimen	1-in. Specimen	1½-in. Specimen	55 000	58 000	65 000	70 000
0.71	1.411 1.429	0.941 0.953	0.706 0.714	0.471 0.476	31.5	30.0	27.0	25.5
0.70	1.390 1.410	0.927 0.940	0.695 0.705	0.464 0.470	31.5	30.0	27.0	25.5
0.69	1.371 1.389	0.914 0.926	0.686 0.694	0.457 0.463	31.5	30.0	27.0	25.5
0.68	1.350 1.370	0.900 0.913	0.675 0.685	0.450 0.456	31.5	30.0	27.0	25.0
0.67	1.331 1.349	0.887 0.899	0.666 0.674	0.444 0.449	31.0	30.0	27.0	25.0
0.66	1.310 1.330	0.874 0.886	0.655 0.665	0.437 0.443	31.0	29.5	27.0	25.0
0.65	1.291 1.309	0.861 0.873	0.646 0.654	0.431 0.436	31.0	29.5	26.5	25.0
0.64	1.270 1.290	0.847 0.860	0.635 0.645	0.424 0.430	31.0	29.5	26.5	25.0
0.63	1.251 1.269	0.834 0.846	0.626 0.634	0.417 0.423	31.0	29.5	26.5	25.0
0.62	1.230 1.250	0.820 0.833	0.615 0.625	0.410 0.416	31.0	29.5	26.5	25.0
0.61	1.211 1.229	0.807 0.819	0.606 0.614	0.404 0.409	30.5	29.0	26.5	24.5
0.60	1.190 1.210	0.794 0.806	0.595 0.605	0.397 0.403	30.5	29.0	26.5	24.5
0.59	1.171 1.189	0.781 0.793	0.586 0.594	0.391 0.396	30.5	29.0	26.0	24.5
0.58	1.150 1.170	0.767 0.780	0.575 0.585	0.384 0.390	30.5	29.0	26.0	24.5
0.57	1.131 1.149	0.754 0.766	0.566 0.574	0.377 0.383	30.5	29.0	26.0	24.5
0.56	1.110 1.130	0.740 0.753	0.555 0.565	0.370 0.376	30.0	28.5	26.0	24.5
0.55	1.091 1.109	0.727 0.739	0.546 0.554	0.364 0.369	30.0	28.5	26.0	24.0
0.54	1.070 1.090	0.714 0.726	0.535 0.545	0.357 0.363	30.0	28.5	25.5	24.0
0.53	1.051 1.069	0.701 0.713	0.526 0.534	0.351 0.356	30.0	28.5	25.5	24.0
0.52	1.030 1.050	0.687 0.700	0.515 0.525	0.344 0.350	29.5	28.5	25.5	24.0
0.51	1.011 1.029	0.674 0.686	0.506 0.514	0.337 0.343	29.5	28.0	25.5	24.0
0.50	0.990 1.010	0.660 0.673	0.495 0.505	0.330 0.336	29.5	28.0	25.5	23.5
0.49	0.971 0.989	0.647 0.659	0.486 0.494	0.324 0.329	29.5	28.0	25.5	23.5
0.48	0.950 0.970	0.634 0.646	0.475 0.485	0.317 0.323	29.0	28.0	25.0	23.5
0.47	0.931 0.949	0.621 0.633	0.466 0.474	0.311 0.316	29.0	27.5	25.0	23.5
0.46	0.910 0.930	0.607 0.620	0.455 0.465	0.304 0.310	29.0	27.5	25.0	23.5
0.45	0.891 0.909	0.594 0.606	0.446 0.454	0.297 0.303	29.0	27.5	25.0	23.0
0.44	0.870 0.890	0.580 0.593	0.435 0.445	0.290 0.296	28.5	27.5	24.5	23.0
0.43	0.851 0.869	0.567 0.579	0.426 0.434	0.284 0.289	28.5	27.5	24.5	23.0
0.42	0.830 0.850	0.554 0.566	0.415 0.425	0.277 0.283	28.5	27.0	24.5	23.0
0.41	0.811 0.829	0.541 0.553	0.406 0.414	0.271 0.276	28.5	27.0	24.5	23.0
0.40	0.790 0.810	0.527 0.540	0.395 0.405	0.264 0.270	28.0	27.0	24.0	22.5
0.39	0.771 0.789	0.514 0.526	0.386 0.394	0.257 0.263	28.0	26.5	24.0	22.5
0.38	0.750 0.770	0.500 0.513	0.375 0.385	0.250 0.256	28.0	26.5	24.0	22.5
0.37	0.731 0.749	0.487 0.499	0.366 0.374	0.244 0.249	27.5	26.5	24.0	22.5
0.36	0.710 0.730	0.474 0.486	0.355 0.365	0.237 0.243	27.5	26.5	23.5	22.0
0.35	0.691 0.709	0.461 0.473	0.346 0.354	0.231 0.236	27.5	26.0	23.5	22.0
0.34	0.670 0.690	0.447 0.460	0.335 0.345	0.224 0.230	27.5	26.0	23.5	22.0
0.33	0.651 0.669	0.434 0.446	0.326 0.334	0.217 0.223	27.0	26.0	23.5	22.0
0.32	0.630 0.650	0.420 0.433	0.315 0.325	0.210 0.216	27.0	25.5	23.0	21.5
0.31	0.611 0.629	0.407 0.419	0.306 0.314	0.204 0.209	27.0	25.5	23.0	21.5
0.30	0.590 0.610	0.394 0.406	0.295 0.305	0.197 0.203	26.5	25.5	23.0	21.5
0.29	0.571 0.589	0.381 0.393	0.286 0.294	0.191 0.196	26.5	25.0	22.5	21.5
0.28	0.550 0.570	0.367 0.380	0.275 0.285	0.184 0.190	26.0	25.0	22.5	21.0
0.27	0.531 0.549	0.354 0.366	0.266 0.274	0.177 0.183	26.0	25.0	22.5	21.0
0.26	0.510 0.530	0.340 0.353	0.255 0.265	0.170 0.176	26.0	24.5	22.0	21.0
0.25	0.491 0.509	0.327 0.339	0.246 0.254	0.164 0.169	25.5	24.5	22.0	20.5
0.24	0.470 0.490	0.314 0.326	0.235 0.245	0.157 0.163	25.5	24.5	22.0	20.5
0.23	0.451 0.469	0.301 0.313	0.226 0.234	0.151 0.156	25.0	24.0	21.5	20.5
0.22	0.430 0.450	0.287 0.300	0.215 0.225	0.144 0.150	25.0	24.0	21.5	20.0
0.21	0.411 0.429	0.274 0.286	0.206 0.214	0.137 0.143	25.0	23.5	21.5	20.0
0.20	0.390 0.410	0.260 0.273	0.195 0.205	0.130 0.136	24.5	23.5	21.0	19.5
0.19	0.371 0.389	0.247 0.259	0.186 0.194	0.124 0.129	24.5	23.0	21.0	19.5
0.18	0.350 0.370	0.234 0.246	0.175 0.185	0.117 0.123	24.0	23.0	20.5	19.5
0.17	0.331 0.349	0.221 0.233	0.166 0.174	0.111 0.116	23.5	22.5	20.5	19.0
0.16	0.310 0.330	0.207 0.220	0.155 0.165	0.104 0.110	23.5	22.5	20.0	19.0
0.15	0.291 0.309	0.194 0.206	0.146 0.154	0.097 0.103	23.0	22.0	20.0	18.5
0.14	0.270 0.290	0.180 0.193	0.135 0.145	0.090 0.096	23.0	22.0	19.5	18.5
0.13	0.251 0.269	0.167 0.179	0.126 0.134	0.084 0.089	22.5	21.5	19.5	18.0
0.12	0.230 0.250	0.154 0.166	0.115 0.125	0.077 0.083	22.0	21.0	19.0	18.0

TABLE X1.1 *Continued*

Area,[A] in.^{2}	Tension Test Specimen				Elongation in 2 in., min, %			
	Specified Wall Thickness, in.[B]				Specified Tensile Strength, psi			
	½-in. Specimen	¾-in. Specimen	1-in. Specimen	1½-in. Specimen	55 000	58 000	65 000	70 000
0.11	0.211 0.229	0.141 0.153	0.106 0.114	0.071 0.076	22.0	21.0	18.5	17.5
0.10	0.190 0.210	0.127 0.140	0.095 0.105	0.064 0.070	21.5	20.5	18.5	17.0
0.09	0.171 0.189	0.114 0.126	0.086 0.094	0.057 0.063	21.0	20.0	18.0	17.0
0.08	0.150 0.170	0.100 0.113	0.075 0.085	0.050 0.056	20.5	19.5	17.5	16.5
0.07	0.131 0.149	0.087 0.099	0.066 0.074	0.044 0.049	20.0	19.0	17.0	16.0
0.06	0.110 0.130	0.074 0.086	0.055 0.065	0.037 0.043	19.5	18.5	16.5	15.5
0.05	0.091 0.109	0.061 0.073	0.046 0.054	0.031 0.036	18.5	17.5	16.0	15.0
0.04	0.070 0.090	0.047 0.060	0.035 0.045	0.024 0.030	18.0	17.0	15.5	14.5
0.03	0.051 0.069	0.034 0.046	0.026 0.034	0.017 0.023	17.0	16.0	14.5	13.5
0.02	0.030 0.050	0.020 0.033	0.015 0.025	0.010 0.016	15.5	15.0	13.5	12.5
0.01	0.011 0.029	0.007 0.019	0.006 0.014	0.004 0.009	13.5	13.0	11.5	11.0

[A] 1 in.^{2}= 645.16 mm^2.
[B] 1 in. = 25.4 mm.

Designation: A 707/A 707M – 02 (Reapproved 2007)

Standard Specification for Forged Carbon and Alloy Steel Flanges for Low-Temperature Service[1]

This standard is issued under the fixed designation A 707/A 707M; 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 covers forged carbon and alloy steel flanges intended primarily for petroleum and gas pipelines in areas subject to low ambient temperatures. Included are flanges to specified dimensions or to dimensional standards such as those MSS, ASME, and API specifications that are referenced in Section 2.

1.2 Supplementary requirements are provided for use when additional requirements are desired. These shall apply only when specified individually by the purchaser in the order.

1.3 Eight grades, four yield-strength classes, and three different notch toughness levels are included.

1.4 The availability of a particular size of flange of a specific grade and class is limited only by the capability of the composition to meet the specified mechanical property requirements. However, current practice normally limits the following:

(a) Grade L1 to Classes 1 and 2,
(b) Grade L2 to Classes 1, 2, and 3,
(c) Grade L3 to Classes 1, 2, and 3,
(d) Grade L4 to Classes 1, 2, and 3,
(e) Grade L7 to Classes 1 and 2, and
(f) Grades L5, L6, and L8 are generally available in any class.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 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.

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A 961/A 961M, the following list of standards apply to this specification:

2.2 *ASTM Standards:* [2]

A 388/A 388M Practice for Ultrasonic Examination of Heavy Steel Forgings

A 788/A 788M Specification for Steel Forgings, General Requirements

A 961/A 961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

2.3 *MSS Standards:*

SP 44 Steel Pipeline Flanges[3]

2.4 *API Standard:*

605 Large Diameter Carbon Steel Flanges[4]

2.5 *ASME Boiler and Pressure Vessel Code:*

Section VIII Division I, Part UG-84[5]

Section IX Welding Qualifications[5]

2.6 *ASME Standard:*

B 16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings[5]

2.7 *AWS Standards:*

A 5.1 Mild Steel Covered Electrodes[6]

A 5.5 Low-Alloy Steel Covered Arc-Welding Electrodes[6]

3. Terminology

3.1 *Definitions:*

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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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] 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.

[3] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602, http://www.mss-hq.com.

[4] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://api-ec.api.org.

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[6] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, http://www.aws.org.

3.1.1 *flakes*—short discontinuous internal fissures attributed to stresses produced by localized transformation and decreased solubility of hydrogen during cooling after hot working.

3.1.2 *linear surface imperfection (or indication)*—an imperfection or indication with a length at least three times its width.

4. Ordering Information

4.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. In addition to the ordering information guide lines in Specification A 961/A 961M, orders should include the following information:

4.1.1 Additional requirements (see Table 1 footnotes, 9.2.2, 9.3, 11.5, 17.1, 21.1, and 21.2).

5. General Requirements

5.1 Product furnished to this specification shall conform to the requirements of Specification A 961/A 961M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 961/A 961M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 961/A 961M, this specification shall prevail.

6. Manufacture

6.1 The steel shall meet the melting practice of Specification A 961/A 961M.

6.2 The finished product shall be a forging as defined by 3 (only) of Specification A 788/A 788M.

7. Heat Treatment

7.1 After forging and before reheating for heat treatment, the forging shall be allowed to cool substantially below the transformation range. The method of cooling shall be such as to ensure against the development of cracks, flakes, etc.

7.2 All material shall be heat treated by annealing, normalizing, precipitation hardening, quenching-and-tempering, normalizing-and-tempering, normalizing-and-precipitation hardening, or quenching-and-precipitation hardening.

7.2.1 The procedures for the various heat treatments are as given in Specification A 961/A 961M except as defined in the following:

7.2.1.1 *Precipitation Hardening*—Consists of heating to a temperature between 1000 and 1250°F [538 and 677°C], holding at temperature for not less than ½ h, and then cooling at any convenient rate.

TABLE 1 Chemical Requirements

Element	Grade							
	L1[A]	L2[A]	L3	L4	L5	L6	L7[B]	L8
Carbon, max, %								
Heat analysis	0.20	0.30	0.22	0.18	0.07	0.07	0.20	0.20
Product analysis	0.23	0.33	0.25	0.20	0.09	0.09	0.22	0.22
Manganese, %								
Heat analysis	0.60-1.50	0.60-1.35	1.15–1.50	0.45–0.65	0.40–0.70	1.85–2.20	0.90 max	0.20–0.40
Product analysis	0.55-1.60	0.55-1.45	1.05–1.60	0.40–0.70	0.35–0.75	1.75–2.30	1.00 max	0.15–0.45
Phosphorus, max, %								
Heat analysis	0.030	0.030	0.025	0.025	0.025	0.025	0.025	0.020
Product analysis	0.035	0.035	0.030	0.030	0.030	0.030	0.030	0.025
Sulfur, max, %								
Heat analysis	0.030	0.030	0.025	0.025	0.025	0.025	0.025	0.020
Product analysis	0.040	0.040	0.035	0.035	0.035	0.035	0.035	0.025
Silicon, max, %								
Heat analysis	0.35	0.35	0.30	0.35	0.35	0.15	0.35	0.35
Product analysis	0.37	0.37	0.32	0.37	0.37	0.17	0.37	0.37
Chromium, %								
Heat analysis	0.30 max	0.30 max	0.30 max	0.30 max	0.60–0.90	0.30 max	0.30 max	1.50–2.00
Product analysis	0.34 max	0.34 max	0.34 max	0.34 max	0.56–0.94	0.34 max	0.34 max	1.44–2.06
Nickel, %								
Heat analysis	0.40 max	0.40 max	0.40 max	1.65–2.00	0.70–1.00	0.40 max	3.2–3.7	2.8–3.9
Product analysis	0.43 max	0.43 max	0.43 max	1.60–2.05	0.67–1.03	0.43 max	3.18–3.82	2.68–3.97
Molybdenum, %								
Heat analysis	0.12 max	0.12 max	0.12 max	0.20–0.30	0.15–0.25	0.25–0.35	0.12 max	0.40–0.60
Product analysis	0.13 max	0.13 max	0.13 max	0.19–0.33	0.14–0.28	0.22–0.38	0.13 max	0.35–0.65
Vanadium, %								
Heat analysis	0.05 max	0.05 max	0.04–0.11	0.05 max	0.05 max	0.05 max	0.05 max	0.05 max
Product analysis	0.06 max	0.06 max	0.03–0.13	0.06 max	0.06 max	0.06 max	0.06 max	0.06 max
Nitrogen, %								
Heat analysis	...	...	0.010–0.030	...	...	...	...	...
Product analysis	...	...	0.005–0.035	...	...	...	...	...
Copper, %								
Heat analysis	0.40 max	0.40 max	0.20 min[C]	0.40 max	1.00–1.30	0.40 max	0.40 max	0.40 max
Product analysis	0.43 max	0.43 max	0.18 min[C]	0.43 max	0.95–1.35	0.43 max	0.43 max	0.43 max
Columbium, %								
Heat analysis	0.02 max	0.02 max	0.02 max	0.02 max	0.03 min	0.06–0.10	0.02 max	0.02 max
Product analysis	0.03 max	0.03 max	0.03 max	0.03 max	0.02 min	0.05–0.11	0.03 max	0.03 max

[A] The sum of copper, nickel, chromium, and molybdenum shall not exceed 1.00 % on heat analysis.
[B] The sum of chromium, molybdenum and vanadium shall not exceed 0.32 % on heat analysis.
[C] When specified.

8. Chemical Composition

8.1 A chemical heat analysis in accordance with Specification A 961/A 961M shall be made and conform to the requirements as to chemical composition prescribed in Table 1. Leaded steels shall not be permitted.

9. Mechanical Requirements

9.1 The material in the weld neck shall conform to the mechanical property requirements prescribed in Table 2.

9.2 For the purpose of determining conformance with Table 2, mechanical testing requirements shall confrom to Specification A 961/A 961M.

9.2.1 For flanges smaller than 24 in. [610 mm] in size, the forged test blanks shall be at least 2 in. [50 mm] wide by 2 in. [50 mm] thick by 12 in. [300 mm] in length. The test specimens shall be taken with their longitudinal axes parallel to the length of the test blank.

9.2.2 For flanges 24 in. [610 mm] and larger in size, the test blank dimensions and orientation of test specimens with respect to the test blank shall be subject to agreement.

9.3 Specimens shall be obtained from the midwall of the thinnest section of the hub of the flange or ¾ in. [19 mm] from the surface of the test blank. The orientation of specimens taken from a flange shall be subject to agreement.

10. Hardness Requirements

10.1 A sufficient number of hardness measurements shall be made to ensure that the hardness values are within the ranges prescribed in Table 2. The number of flanges to be tested shall be as agreed upon between the manufacturer and the purchaser. The purchaser may verify that the requirement has been met by testing at any location on the flange, provided such testing does not render the flange useless.

11. Impact Requirements

11.1 The material in the weld neck shall conform to the requirements as to impact properties prescribed in Table 2 if the weld neck section is ¼ in. [6 mm] or greater in thickness.

11.2 For the purpose of determining conformance with Table 2, specimens shall be obtained from production flanges after heat treatment or from separately forged test blanks prepared from the stock used to make the forgings. Such test blanks shall conform to the requirements of Specification A 961/A 961M.

11.3 Specimens shall be obtained from a location on the flange or test blank that represents the midwall of the weld neck if the thickness of the weld neck is 2 in. [50 mm] or less. If the thickness is greater than 2 in. [50 mm], the specimen location shall be midway between a surface and the center of thickness. Specimens taken from a flange shall be oriented longitudinally with respect to the bore of the flange.

11.4 One test (three specimens) shall be made from each heat in each heat treatment charge.

11.5 Unless otherwise specified, the test temperature shall be as specified in Table 3.

12. Product Analysis

12.1 The purchaser may make a product analysis on flanges supplied to this specification in accordance with Specificaiton A 961/A 961M.

13. Ultrasonic Examination

13.1 Each flange weld neck 24 in. [610 mm] and larger in diameter shall be ultrasonically examined over 100 % of the area within 2 in. [50 mm] of the welding end.

13.2 Longitudinal wave examination using a 2¼ MHz transducer 1 to 1⅛ in. [25 to 29 mm] in diameter or 1 in. square [25 mm square] shall be used. Examination shall be in accordance with the general requirements of Practice A 388/A 388M.

13.3 Any area giving an indication equal to or larger than the signal received from a ¼-in. [6-mm] flat-botton hole shall be cause for rejection. Multiple indications with an amplitude exceeding 50 % of the indication from the calibration hole, accompanied by a loss of back reflection exceeding 50 %, shall also be cause for rejection. Any indication that results in a complete loss of back reflection shall be cause for rejection.

14. Tension Tests

14.1 Tensile requirements shall comply with Specification A 961/A 961M where one tension test shall be made from each heat in each heat treating charge.

TABLE 2 Mechanical Requirements

Property	Class 1	Class 2	Class 3	Class 4
Yield strength[A] min, ksi [MPa]	42 [290]	52 [360]	60 [415]	75 [515]
Tensile strength, min, ksi [MPa]	60 [415]	66 [455]	75 [515]	90 [620]
Elongation in 2 in. or 50 mm, min, %	22	22	20	20
Reduction of area, min, %	40	40	40	40
Hardness, HBN	149–207	149–217	156–235	179–265
Cv energy absorption,[B,C] min, avg, ft·lbf [J]	30 [41]	40 [54]	50 [68]	50 [68]
C_v energy absorption,[B,D] min, ft·lbf [J]	24 [33]	32 [43]	40 [54]	40 [54]

[A] 0.2 % offset.

[B] For a set of three full-size [10 by 10 mm] Charpy V-notch specimens. Acceptance values for sub-size specimens are reduced in proportion to the reduction in width of the specimen.

[C] These requirements are intended to minimize fracture initiation. They are not intended to give assurance against fracture propagation. If minimization of fracture propagation is of interest, consideration should be given to specifying Supplementary Requirement S7 at the operating temperature.

[D] Minimum impact energy permitted for one specimen only of a set of three specimens.

TABLE 3 Impact Test Temperatures[A]

Grade	Test Temperature (Unless Otherwise Specified), °F [°C]
L1	−20 [−29]
L2	−50 [−46]
L3	−50 [−46]
L4	−80 [−62]
L5	−80 [−62]
L6	−80 [−62]
L7	−100 [−73]
L8	−100 [−73]

[A] These temperatures are the lowest test temperatures that are commonly acceptable by the producer. If the minimum design temperature is higher, specifying the higher temperature as the test temperature will generally result in increased availability of a specific grade in greater thicknesses.

14.1.1 When the heat treating temperatures are the same and the furnaces (either batch or continuous type) are controlled within ±25°F [±14°C] and equipped with recording pyrometers so that complete records of heat treatment are available, then one tension test from each heat is required instead of one test from each heat in each heat treatment charge. The test specimen material shall be included with a furnace charge.

15. Hydrostatic Tests

15.1 Forgings manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the finished flange. Such tests shall be conducted by the manufacturer only when Supplementary Requirement S8 of Specification A 961/A 961M is specified.

16. Retreatment

16.1 If the results of the mechanical property or impact tests do not conform to the requirement specified, the manufacturer may reheat treat the flanges as applicable and repeat the tests specified.

17. Workmanship, Finish, and Appearance

17.1 In addition to the requirements of Specification A 961/A 961M, the flanges shall be free of injurious imperfections as defined below and shall have a workmanlike finish.

17.1.1 *Welding End*— The machined bevel shall be visually examined. Any lamination extending into the weld bevel and having a transverse dimension exceeding ¼ in. [6 mm] shall be considered injurious.

17.1.2 *Hub Section*—Linear imperfections with a length in excess of ⅛ in. [3 mm] and other imperfections such as slivers, sharp notches, gouges, scores, pits, etc., shall be considered injurious.

18. Repair by Welding

18.1 Repair of imperfections shall be permitted only with the approval of the purchaser. When approved, the limitations and requirements of Specification A 961/A 961M shall apply:

18.1.1 In addition, the deposited weld metal shall be capable of producing welds with mechanical and impact test properties as specified in Table 2 at the test temperature specified in Table 3 for the base metal after the thermal treatments in 18.1.2. SMAW (using only low-hydrogen electrodes), GMAW, FCAW or GTAW may be used. Electrodes shall conform to the applicable AWS A5 electrode specification. The GMAW process is limited to either the spray transfer or pulsed arc process. FCAW process is limited to repair of carbon or carbon-molybdenum base materials only. Welding procedures shall be qualified in accordance with Section IX and Paragraph UG-84, Section VIII, Div. 1, of the Code.

18.1.2 All flanges repaired by welding shall be thermally treated after repair by either complete reheat treatment or post-weld heat treatment.

18.1.3 Indications discovered by ultrasonic inspection shall be reinspected in accordance with Section 13 after reheat treatment.

19. Inspection

19.1 Inspection provisions of Specification A 961/A 961M apply.

20. Rejection and Rehearing

20.1 Each flange that develops injurious imperfections during shop working or application shall be rejected and the manufacturer notified.

20.2 Purchaser shall comply with provisions of Specification A 961/A 961M.

21. Certification

21.1 For flanges made to specified dimensions, when agreed upon by the purchaser, and for flanges made to dimensional standards, application of identification marks as required in 22.1 shall be the certification that the flanges have been furnished in accordance with the requirements of the specification.

21.2 When test reports are required, they shall include certification that all requirements of this specification have been met, the results of all required tests, and description of heat treatment including temperature ranges, times, mode of cooling, and the heat number or manufacturer's heat identification. The specification designation included on test reports shall include year of issue and revision letter, if any.

22. Product Marking

22.1 In addition to the marking requirements of Specification A 961/A 961M, the impact test temperature shall be legibly stamped on each flange.

NOTE 1—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification, and the results have been determined to meet the requirements of this specification.

22.1.1 If the flanges have been quenched-and-tempered or quenched-and-aged the letters QT or QA, as applicable, shall be stamped on the flanges following the ASTM designation.

22.1.2 Forgings repaired by welding shall be marked with the letter "W" following the ASTM designation.

22.2 When test reports are required, the markings shall include such other markings as necessary to identify the part with the test report.

22.3 *Bar Coding*—In addition to the requirements in 22.1 and 22.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

23. Keywords

23.1 carbon equivalent; piping applications; pressure containing parts; residual elements; steel flanges; steel forgings, alloy; steel forgings, carbon; temperature service applications; low

SUPPLEMENTARY REQUIREMENTS

In addition to any of the supplementary requirements of Specification A 961/A 961M, the following supplementary requirements shall apply only when specified by the purchaser in the order:

S1. Ultrasonic Examination

S1.1 Flanges smaller than 24 in. [610 mm] shall be ultrasonically examined in accordance with Section 13.

S2. Additional Tension and Impact Tests

S2.1 In addition to the requirements of Sections 9, 10, 11 and 14, one tension specimen and one set of impact specimens shall be obtained from a representative flange at a location agreed upon between the manufacturer and purchaser. The results of these specimens shall comply with the requirements of Table 3 and Table 1 and shall be reported to the purchaser.

S3. Carbon Equivalent

S3.1 The maximum carbon equivalent, based on heat analysis, for Grades L1, L2, and L3 shall be as shown in Table S3.1:

S3.2 Determine the carbon equivalent (CE) as follows:

TABLE S3.1 Maximum Carbon Equivalent Value

Class	Maximum Thickness Less Than or Equal to 2 in.	Maximum Thickness Greater Than 2 in.
1	0.45	0.46
2	0.45	0.46
3	0.47	0.48

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

S3.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

S4. Notch Toughness, 50 % Shear FATT Minimum

S4.1 In addition to the requirements of Section 11, the impact specimens shall exhibit a minimum of 50 % shear fracture appearance at the temperature specified on the order.

S5. Additional Ultrasonic Test Requirement

S5.1 In addition to the requirements of Section 13, flanges shall be tested by the angle beam method in accordance with Practice A 388/A 388M. Testing shall be limited to an area within 2 in. [50 mm] of the welding end. Acceptance limits shall be as agreed upon between the manufacturer and purchaser.

S6. Notch Toughness, Measurement, and Reporting of Percent Shear and Lateral Expansion

S6.1 In addition to the requirements of Section 11, percent shear and mils of lateral expansion shall be measured and reported for informational purposes.

Designation: A 694/A 694M – 03

Standard Specification for Carbon and Alloy Steel Forgings for Pipe Flanges, Fittings, Valves, and Parts for High-Pressure Transmission Service[1]

This standard is issued under the fixed designation A 694/A 694M; 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 covers forged or rolled steel pipe flanges, forged fittings, valves, and parts suitable for use with high-strength transmission-service pipe. Included are flanges, fittings, and similar parts ordered either to dimensions specified by the purchaser or to ASME or MSS dimensional standards referenced in Section 2.

1.2 Several grades of material, based on minimum yield strength requirements, are covered, as indicated in Table 1.

1.3 Supplementary Requirements are provided. Supplementary Requirement S 1 is provided for use when purchaser approval is required for repair welding.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 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.

TABLE 1 Tensile Requirements

Grade	Yield Strength (0.2 % Offset), min, ksi [MPa]	Tensile Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min %
F42	42 [290]	60 [415]	20
F46	46 [315]	60 [415]	20
F48	48 [330]	62 [425]	20
F50	50 [345]	64 [440]	20
F52	52 [360]	66 [455]	20
F56	56 [385]	68 [470]	20
F60	60 [415]	75 [515]	20
F65	65 [450]	77 [530]	20
F70	70 [485]	82 [565]	18

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A 961, the following list of standards apply to this specification:

2.2 *ASTM Standards:* [2]

A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

A 106 Specification for Seamless Carbon Steel Pipe for High-Temperature Service

A 381 Specification for Metal-Arc-Welded Steel Pipe for Use with High-Pressure Transmission Systems

A 707/A 707M Specification for Forged Carbon and Alloy Steel Flanges for Low-Temperature Service

A 788 Specification for Steel Forgings, General Requirements

A 961 Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

2.3 *ASME Standards:*

ASME B 16.5 Steel Pipe Flanges and Flanged Fittings[3]

ASME B 16.9 Steel Butt-Welding Fittings[3]

ASME B 16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves[3]

ASME B 16.11 Forged Steel Fittings, Socket Welding and Threaded[3]

ASME B 16.28 Wrought Steel Butt-Welding Short Radius Elbows[3]

ASME B 16.47 Large Diameter Steel Flanges[3]

2.4 *MSS Standards:*[4]

MSS SP-44 Standard for Steel Pipe Line Flanges

MSS SP-75 Specification for High-Test Welding Fittings

MSS SP-95 Swage (d) Nipples and Bull Plugs

MSS SP-97 Integrally Reinforced Forged Branch Outlet Fittings

2.5 *API Standard:*

[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 A01.22 on Valves and Fittings.

Current edition approved October 1, 2003. Published November 2003. Originally approved in 1974. Last previous edition approved in 2000 as A 694/A 694M – 00.

[2] 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.

[3] Available from American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

[4] Available from the Manufacturers' Standardization Society of the Valve and Fittings Industry, 127 Park St., Northeast, Vienna, VA 22180.

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

5L Specification for Line Pipe[5]

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. In addition to the ordering guidelines in Specification A 961, orders should include the following information:

3.1.1 Additional requirements (see 8.1 and 10.1).

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 961, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 961 constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 961, this specification shall prevail.

5. Manufacture

5.1 *Melting Process*:

5.1.1 The steel shall be made by any of the following processes: open hearth, electric furnace, or basic oxygen. The steel shall be fully deoxidized.

5.1.2 The steel shall be carbon steel, high-strength low-alloy steel, or alloy steel, as agreed upon between the manufacturer and purchaser. Analysis of the steel used, including all alloying elements, shall be reported by the manufacturer to the purchaser. The steel shall be suitable for field welding (as established by the purchaser) to other fittings, valve materials and flanges, and to pipe manufactured under the following ASTM specifications: Specification A 53, Specification A 106, Specification A 381, and API Standard 5L pipe, as well as to fittings manufactured under MSS SP-75.

5.2 *Manufacturing Practice*:

5.2.1 Material for forgings shall consist of ingots or blooms, billets, slabs, or bars of forged or rolled form and cut to the required length by a suitable process.

5.2.2 The finished product shall be a forging as defined in the Terminology section of Specification A 788.

5.2.3 Hot working shall be sufficient to develop a wrought structure throughout the part.

5.2.4 Flanges shall not be machined directly from plate nor from solid bar stock.

5.3 *Heat Treatment*:

5.3.1 All items shall be heat treated. Heat treatment of carbon steel and high-strength low-alloy steel may consist of normalizing, normalizing-and-tempering, or quenching-and-tempering. Heat treatment of alloy steel may consist of normalizing and precipitation heat treatment or quenching and precipitation heat treatment.

5.3.2 The tempering temperature shall be at least 1000°F [540°C]. The precipitation heat treatment of the alloy steel shall be in the range from 1000 to 1225°F [540 to 665°C].

[5] Available from American Petroleum Institute, 1801 K St. N. W., Washington, DC 20037.

6. Chemical Composition

6.1 A chemical heat analysis in accordance with Specification A 961 shall be made and conform to the requirements as to chemical composition prescribed in Table 2.

6.2 High-strength low-alloy steels shall be of specified alloy element composition, with the elements covered in 6.1 restricted within the limits prescribed therein as may be necessary to ensure weldability and specified minimum tensile properties. When high-strength low-alloy steel is furnished, appropriate procedures are required for field welding.

6.3 Alloy steel shall conform to the requirements for Grade L 5 of Specification A 707/A 707M .

7. Tensile Requirements

7.1 The material shall conform to the requirements as to tensile properties prescribed in Table 1, when tested in accordance with the mechanical testing requirements of Specification A 961.

7.2 The tension test specimen shall be obtained from a production forging, or from an integral prolongation representative of the hub location of a flange, or the heaviest cross section of a fitting, valve, or other part within the scope of this specification. Alternatively, the test specimen may be taken from a separately forged test block which has been taken from the same heat of steel as the production forgings, and which has been reduced by forging in a manner similar to that for the forgings it represents.

7.2.1 The test specimen shall represent all forgings from the same heat and heat treatment load whose maximum thicknesses do not exceed the thickness of the test forging or blank by more than ¼ in. [6 mm].

7.3 The axis of the tension test sample shall be located in the test forging, or prolongation so as to represent mid-wall of the flange hub, or mid-wall of the thickest cross section of the valve, fitting, or other part.

7.4 The axis of the tension test specimen shall be oriented parallel to the direction of maximum forging work for fittings, valves, and other parts, except for flanges when the specimen shall be oriented in the tangential direction.

7.5 One tension test shall be taken from each heat in each heat treatment load, and shall be representative of the largest flange hub, or valve or fitting wall thickness in the load.

7.6 When heat treatment is done either continuous or batch type furnaces in which the working zones are controlled to within +/- 25°F [+/- 14°C] of the required heat treatment temperature, and when the furnace is equipped with functioning recording pyrometers such that complete heat treatment records are available, then one tension test from each heat shall be required instead of from each heat in each heat treatment

TABLE 2 Chemical Requirements

	Composition, %	
	Heat Analysis	Product Analysis
Carbon, max	0.26	0.265
Manganese, max	1.40	1.44
Phosphorus, max	0.025	0.030
Sulfur, max	0.025	0.030
Silicon	0.15–0.35	0.10–0.40

load. However, this provision is limited to forgings with heat treated weights not exceeding 10 000 lbs [4540 kg], and the test forging must accompany a production charge.

8. Workmanship, Finish, and Appearance

8.1 The forgings shall be free of injurious defects as defined in Specification A 961.

8.2 *Repair by Welding of Injurious Defects*—Repair of injurious defects shall be permitted at the discretion of the manufacturer in accordance with Specification A 961.

8.2.1 Deposited weld metal shall be capable of meeting all mechanical properties upon heat treatment.

8.2.2 All forgings to be repaired by welding shall be repair welded prior to heat treatment.

9. Retests

9.1 If any of the results of the tension tests of any lot do not conform to the requirements specified, the manufacturer may reheat treat such lots, but not more than twice, except with the approval of the purchaser, on the basis of satisfactory metallurgical evidence that the cause of failure is curable and the quality of the material is satisfactory.

10. Rejection and Rehearing

10.1 The purchaser shall comply with the requirements of Specification A 961.

11. Certification

11.1 Certification shall comply with Specification A 961. However, if high-strength low-alloy steel is used, the analysis and the heat number or manufacturer's heat identification shall be reported to the purchaser.

12. Product Marking

12.1 Product marking shall comply with Specification A 961.

12.2 Forgings repaired by welding shall be marked with the letter "W" following the ASTM designation.

12.3 *Bar Coding*—In addition to the requirements in 12.1 and 12.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

13. Keywords

13.1 high strength low alloy steel; pipe fittings, steel; piping applications; pressure containing parts; steel flanges; steel forgings, alloy; steel forgings, carbon; steel valves

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, and order:

S1. Special Flanges

S1.1 Flanges shall meet the requirements of MSS SP-44, except the chemical requirements shall conform to Table 2.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 694/A 694M - 00, which may impact the use of this specification. (Approved October 1, 2003)

(*1*) Revised Section 10 to reference Specification A 961 requirements.

Designation: A 691 – 98 (Reapproved 2002)

Standard Specification for Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures[1]

This standard is issued under the fixed designation A 691; 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 carbon and alloy steel pipe, electric-fusion-welded with filler metal added, fabricated from pressure-vessel-quality plate of several analyses and strength levels and suitable for high-pressure service at high temperatures. Heat treatment may or may not be required to attain the desired mechanical properties or to comply with applicable code requirements. Supplementary requirements are provided for use when additional testing or examination is desired.

1.2 The specification nominally covers pipe 16 in. (405 mm) in outside diameter and larger with wall thicknesses up to 3 in. (75 mm) inclusive. Pipe having other dimensions may be furnished provided it complies with all other requirements of this specification.

1.3 Several grades and classes of pipe are provided.

1.3.1 *Grade* designates the type of plate used as listed in Table 1.

1.3.2 *Class* designates the type of heat treatment performed in the manufacture of the pipe, whether the weld is radiographically examined, and whether the pipe has been pressure tested as listed in 1.3.3.

1.3.3 Class designations are as follows (Note 1):

Class	Heat Treatment on Pipe	Radiography, see Section	Pressure Test, see Section
10	none	none	none
11	none	9	none
12	none	9	8.3
13	none	none	8.3
20	stress relieved, see 5.3.1	none	none
21	stress relieved, see 5.3.1	9	none
22	stress relieved, see 5.3.1	9	8.3
23	stress relieved, see 5.3.1	none	8.3
30	normalized, see 5.3.2	none	none
31	normalized, see 5.3.2	9	none
32	normalized, see 5.3.2	9	8.3
33	normalized, see 5.3.2	none	8.3
40	normalized and tempered, see 5.3.3	none	none
41	normalized and tempered, see 5.3.3	9	none
42	normalized and tempered, see 5.3.3	9	8.3
43	normalized and tempered, see 5.3.3	none	8.3
50	quenched and tempered, see 5.3.4	none	none
51	quenched and tempered, see 5.3.4	9	none
52	quenched and tempered, see 5.3.4	9	8.3
53	quenched and tempered, see 5.3.4	none	8.3

NOTE 1—Selection of materials should be made with attention to temperature of service. For such guidance, Specification A 20/A 20M may be consulted.

1.4 Optional requirements of a supplementary nature are provided, calling for additional tests and control of repair welding, when desired.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels[3]
A 204/A 204M Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum[3]
A 299/A 299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon[3]
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[4]
A 387/A 387M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum[3]
A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates[3]
A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe[5]
A 537/A 537M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel[3]
E 165 Test Method for Liquid Penetrant Examination[6]
E 709 Practice for Magnetic Particle Examination[6]

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved June 10, 1998. Published October 1998. Originally published as A 691 – 74. Last previous edition A 691 – 96.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-691 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.04.
[4] *Annual Book of ASTM Standards*, Vol 01.03.
[5] *Annual Book of ASTM Standards*, Vol 01.01.
[6] *Annual Book of ASTM Standards*, Vol 03.03.

TABLE 1 Plate Materials

Pipe Grade	Type of Steel	ASTM Specification		HB, max[A]
		Number	Grade	
CM-65	carbon-molybdenum steel	A 204/A 204M	A	201
CM-70	carbon-molybdenum steel	A 204/A	B	201
CM-75	carbon-molybdenum steel	A 204/A 204M	C	201
CMSH-70	carbon-manganese-silicon steel, normalized	A 537/A 537M	1	
CMS-75	carbon-manganese-silicon steel	A 299/A 299M	. . .	. . .
CMSH-80	carbon-manganese-silicon steel, quenched and tempered	A 537/A 537M	2	
½ CR	½ % chromium, ½ % molybdenum steel	A 387/A 387M	2	201
1CR	1 % chromium, ½ % molybdenum steel	A 387/A 387M	12	201
1¼ CR	1¼ % chromium, ½ % molybdenum steel	A 387/A 387M	11	201
2¼ CR	2¼ % chromium, 1 % molybdenum steel	A 387/A 387M	22	201
3CR	3 % chromium, 1 % molybdenum steel	A 387/A 387M	21	201
5CR	5 % chromium, ½ % molybdenum steel	A 387/A 387M	5	225
9CR	9 % chromium, 1 % molybdenum steel	A 387/A 387M	9	241
91	9 % chromium, 1 % molybdenum, vanadium, columbium	A 387/A 387M	91	241

[A] Hardness values listed are applicable to S3.

2.2 *ASME Boiler and Pressure Vessel Code:*[7]
Section II, Material Specifications
Section III, Nuclear Power Plant Components
Section VIII, Unfired Pressure Vessels
Section IX, Welding Qualifications

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 A *lot* shall consist of 200 ft (61 m) or fraction thereof of pipe from the same heat of steel.

3.1.1.1 The description of a lot may be further restricted by use of Supplementary Requirement S12.

4. Ordering Information

4.1 The inquiry and order for material under this specification should include the following information:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of the material (steel pipe, electric-fusion-welded),

4.1.3 Specification number,

4.1.4 Grade and class designations (see 1.3),

4.1.5 Size (inside or outside diameter, nominal or minimum wall thickness),

4.1.6 Length (specific or random),

4.1.7 End finish,

4.1.8 Purchase options, if any (see 5.2.3, 11.3, 11.4, 13.1), and

4.1.9 Supplementary requirements, if any (refer to S1 through S12).

5. Materials and Manufacture

5.1 *Materials*—The steel plate material shall conform to the requirements of the applicable plate specification for the pipe grade ordered as listed in Table 1.

5.2 *Welding*:

5.2.1 The joints shall be double-welded full-penetration welds made in accordance with procedures and by welders or welding operators qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

5.2.2 The welds shall be made either manually or automatically by an electric process involving the deposition of filler metal.

5.2.3 The welded joints shall have positive reinforcement at the center of each side of the weld, but no more than ⅛ in. (3.2 mm). This reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be smooth, and the deposited metal shall be fused smoothly and uniformly into the plate surface.

5.2.4 When radiographic examination in accordance with 9.1 is to be used, the weld reinforcement shall be governed by the more restrictive provisions of UW-51 of Section VIII of the ASME Boiler and Pressure Vessel Code instead of 5.2.3 of this specification.

5.3 *Heat Treatment*—All classes other than 10, 11, 12, and 13 shall be heat treated in a furnace controlled to ± 25°F (14°C) and equipped with a recording pyrometer so that heating records are available. Heat treating after forming and welding shall be to one of the following:

5.3.1 Classes 20, 21, 22, and 23 pipe shall be uniformly heated within the post-weld heat-treatment temperature range indicated in Table 2 for a minimum of 1 h/in. of thickness or for 1 h, whichever is greater.

5.3.2 Classes 30, 31, 32, and 33 pipe shall be uniformly heated to a temperature in the austenitizing range and not exceeding the maximum normalizing temperature indicated in Table 2 and subsequently cooled in air at room temperature.

5.3.3 Classes 40, 41, 42, and 43 pipe shall be normalized in accordance with 5.3.2. After normalizing, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at temperature for a minimum of ½ h/in. of thickness or for ½ h, whichever is greater, and air cooled.

5.3.4 Classes 50, 51, 52, and 53 pipe shall be uniformly heated to a temperature in the austenitizing range, and not exceeding the maximum quenching temperature indicated in Table 2 and subsequently quenched in water or oil. After quenching, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at that temperature for a minimum of ½ h/in. of thickness or for ½ h, whichever is greater, and air cooled.

[7] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

TABLE 2 Heat Treatment Parameters

Pipe Grade	ASTM Specification	Post-Weld Heat-Treat Temperature Range (Stress Relieving), °F (°C)	Normalizing Temperature, max unless otherwise noted, °F (°C)	Quenching Temperature, max unless otherwise noted, °F (°C)	Tempering Temperature, min, °F (°C)
CM-65	A 204/A 204M	1100 to 1200 (590 to 650)	1700 (925)	. . .	. . .
CM-70	A 204/A 204M	1100 to 1200 (590 to 650)	1700 (925)	. . .	. . .
CM-75	A 204/A 204M	1100 to 1200 (590 to 650)	1700 (925)	. . .	. . .
CMSH-70	A 537/A 537M	1100 to 1200 (590 to 650)	1700 (925)	. . .	. . .
CMS-75	A 299/A 299M	1100 to 1200 (590 to 650)	1700 (925)	. . .	. . .
CMSH-80	A 537/A 537M	1100 to 1200 (590 to 650)	[A]	1700 (925)	1100 to 1250 (590 to 675)
½CR	A 387/A 387M	1100 to 1300 (590 to 705)	1850 (1010)	1700 (925)	1150 to 1375 (620 to 745)
1CR	A 387/A 387M	1100 to 1350 (590 to 730)	1850 (1010)	1700 (925)	1150 to 1375 (620 to 745)
1¼CR	A 387/A 387M	1100 to 1375 (590 to 745)	1850 (1010)	1700 (925)	1150 to 1375 (620 to 745)
2¼CR	A 387/A 387M	1200 to 1400 (650 to 760)	1850 (1010)	1700 (925)	1250 to 1400 (675 to 760)
3CR	A 387/A 387M	1200 to 1400 (650 to 760)	1850 (1010)	1700 (925)	1250 to 1400 (675 to 760)
5CR	A 387/A 387M	1200 to 1400 (650 to 760)	1850 (1010)	1650 (900)	1300 to 1400 (705 to 760)
9CR	A 387/A 387M	1325 to 1375 (715 to 745)	[B]	. . .	1325 to 1375 (715 to 745)
91	A 387/A 387M	1350 to 1420 (730 to 770)	1900 to 2000 (1040 to 1095)	1900 min (1040 min)	1350 to 1440 (730 to 780)

[A] Requires quenching and tempering.
[B] 9 CR steel is an air-hardenable steel, at times retaining austenite down to near atmospheric temperature. Good practice is to allow the steel to cool to 150°F or lower before subjecting the steel to a tempering treatment or post-weld heat treatment.

5.4 Grade 91 shall be produced only to classes 4X and 5X. In addition, post-weld heat treatment is required after weld repair.

6. General Requirements

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M, unless otherwise provided herein.

7. Chemical Requirements

7.1 *Product Analysis of Plate*—The pipe manufacturer shall make an analysis of each mill heat of plate material. The product analysis so determined shall meet the requirements of the plate specification to which the material was ordered.

7.2 *Product Analysis of Weld*—The pipe manufacturer shall make an analysis of finished deposited weld metal from each 200 ft (61 m) or fraction thereof. Analysis shall conform to the welding procedure for deposited weld metal.

7.3 Analysis may be taken from the mechanical test specimens. The results of the analyses shall be reported to the purchaser.

7.4 If the analysis of one of these tests specified in 7.1 or 7.2 does not conform to the requirements specified, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified. Nonconforming pipe shall be rejected.

8. Mechanical Requirements

8.1 *Tension Test*:

8.1.1 *Requirements*—Transverse tensile properties of the welded joint shall meet the minimum requirements for ultimate tensile strength of the specified plate material.

8.1.2 *Number of Tests*—One test specimen shall be made to represent each lot of finished pipe.

8.1.3 *Test Specimen Location and Orientation*—The test specimen shall be made transverse to the weld at the end of the finished pipe and may be flattened cold before final machining to size.

8.1.4 *Test Method*—The test specimen shall be made in accordance with QW-150 in Section IX of the ASME Boiler and Pressure Vessel Code. The test specimen shall be tested at room temperature in accordance with Test Methods and Definitions A 370.

8.2 *Transverse-Guided-Weld-Bend Tests*:

8.2.1 *Requirements*—The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. (3.2 mm) in any direction be present in the weld metal or between the weld and the pipe metal after bending. Cracks that originate along the edges of the specimens during testing, and that are less than ¼ in. (6.3 mm) in any direction shall not be considered.

8.2.2 *Number of Tests*—One test (two specimens) shall be made to represent each lot of finished pipe.

8.2.3 *Test Specimen Location and Orientation*—Two bend test specimens shall be taken transverse to 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 as the pipe, the test plate being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal weld seam.

8.2.4 *Test Method*—Bend tests shall be made in accordance with Test Methods and Definitions A 370, A 2.5.1.7. For wall thicknesses over ⅜ in. (9.5 mm) but less than ¾ in. (19.0 mm) side-bend tests may be made instead of the face and root-bend tests. For wall thicknesses ¾ in. and over both specimens shall be subjected to the side-bend test.

8.3 *Pressure Test*—Classes X2 and X3, pipe shall be tested in accordance with Section 20 of Specification A 530/A 530M.

9. Radiographic Examination

9.1 The full length of each weld of classes X1 and X2 shall be radiographically examined in accordance with requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Paragraph UW-51.

9.2 Radiographic examination may be performed prior to heat treatment.

10. Rework

10.1 *Elimination of Surface Imperfections*—Unacceptable surface imperfections shall be removed by grinding or machining. The remaining thickness of the section shall be no less than the minimum specified in Section 11. The depression after grinding or machining shall be blended uniformly into the surrounding surface.

10.2 *Repair of Base Metal Defects by Welding*:

10.2.1 The manufacturer may repair, by welding, base metal where defects have been removed, provided the depth of the repair cavity as prepared for welding does not exceed ⅓ of the nominal thickness, and the requirements of 10.2.2, 10.2.3, 10.2.4, 10.2.5, and 10.2.6 are met. Base metal defects in excess of these may be repaired with prior approval of the customer.

10.2.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair welding.

10.2.3 The welding procedure and welders or welding operators are to be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10.2.4 The full length of the repaired pipe shall be heat treated after repair in accordance with the requirements of the pipe class specified.

10.2.5 Each repair weld of a defect where the cavity, prepared for welding, has a depth exceeding the lesser of ⅜ in. (9.5 mm) or 10 % of the nominal thickness shall be examined by radiography in accordance with the methods and the acceptance standards of Section 9.

10.2.6 The repair surface shall be blended uniformly into the surrounding base metal surface and examined and accepted in accordance with Supplementary Requirements S6 or S8.

10.3 *Repair of Weld Metal Defects by Welding*:

10.3.1 The manufacturer may repair weld metal defects if he meets the requirements of 10.2.3, 10.2.4, 10.3.2, 10.3.3, and 10.4.

10.3.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the repair cavity examined and accepted in accordance with Supplementary Requirements S7 or S9.

10.3.3 The weld repair shall be blended uniformly into the surrounding metal surfaces and examined and accepted in accordance with 9.1 and with Supplementary Requirements S7 or S9.

10.4 *Retest*—Each length of repaired pipe of a class requiring a pressure test shall be hydrostatically tested following repair.

11. Dimensions, Mass, and Permissible Variations

11.1 The wall thickness and weight for welded pipe furnished to this specification shall be governed by the requirements of the specification to which the manufacturer ordered the plate.

11.2 Permissible variations in dimensions at any point in a length of pipe shall not exceed the following:

11.2.1 *Outside Diameter*—Based on circumferential measurement, ± 0.5 % of the specified outside diameter.

11.2.2 *Out-of-Roundness*—The difference between major and minor outside diameters, 1 %.

11.2.3 *Alignment*—Using a 10-ft (3-m) straightedge placed so that both ends are in contact with the pipe, ⅛ in. (3.2 mm).

11.2.4 *Thickness*—The minimum wall thickness at any point in the pipe shall not be more than 0.01 in. (0.3 mm) under the specified nominal thickness.

11.3 Circumferential welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

11.4 Lengths with unmachined ends shall be within −0, +½ in. (−0, +13 mm) of that specified. Lengths with machined ends shall be as agreed between the manufacturer and the purchaser.

12. Workmanship, Finish, and Appearance

12.1 The finished pipe shall be free of injurious defects and shall have a workmanlike finish. This requirement is to mean the same as the identical requirement that appears in Specification A 20/A 20M with respect to steel plate surface finish.

13. Product Marking

13.1 The marking shall be stenciled using a suitable heat-resistant paint or metal stamped using low-stress stamps. Wall thicknesses under 0.500 in. (12.7 mm) shall not be metal stamped without prior approval. The purchaser may specify that material 0.500 in. (12.7 mm) and over shall not be metal stamped.

13.2 In addition to the marking provision of Specification A 530, the class marking in accordance with 1.3.3 shall follow the grade marking, for example, 3CR-33.

13.3 *Bar Coding*—In addition to the requirements in 13.1 and 13.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser, Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Tension and Bend Tests

S1.1 Tension tests in accordance with 8.1 and bend tests in accordance with 8.2 shall be made on specimens representing each length of pipe.

S2. Charpy V-Notch Test (for pipe with nominal wall thickness of ½in. (12.7 mm) and greater)

S2.1 *Requirements*—The acceptable test energies shall be as shown in Table number A1.15 of Specification A 20/A 20M for the applicable plate specification unless otherwise stated in the order. As an alternative, the test temperature may be 10°F (−12°C).

S2.2 *Number of Specimens*—Each test shall consist of at least three specimens.

S2.2.1 One base-metal test shall be made from one pipe length per heat, per heat-treat charge, and per nominal wall thickness.

S2.2.2 One weld-metal and one heat-affected zone (HAZ) metal test shall be made in accordance with NB 4335 of Section III of the ASME Boiler and Pressure Vessel Code.

S2.3 *Test Specimen Location and Orientation:*

S2.3.1 Base-metal specimens of stress-relieved, normalized, and normalized and tempered pipe shall be taken in accordance with the provisions for tension specimens in the body of this specification.

S2.3.2 Base-metal specimens of quenched and tempered pipe shall be taken in accordance with the provisions of NB 2225 of Section III of the ASME Boiler and Pressure Vessel Code.

S3. Hardness Tests

S3.1 Hardness determination shall be made on both ends of each length of pipe to the parent metal, weld, and the heat-affected zone and must meet the hardness requirements in Table 1.

S4. Product Analysis

S4.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical requirements prescribed in the applicable specification listed in Table 1 shall be rejected.

S5. Metallography

S5.1 The manufacturer shall furnish one photomicrograph to show the microstructure at 100× magnification of the weld metal or base metal of the pipe in the as-finished condition. The purchaser shall state in the order: the material, base metal or weld, and the number and locations of tests to be made. This test is for information only.

S6. Magnetic Particle Examination of Base Metal

S6.1 All accessible surfaces of the pipe shall be examined in accordance with Practice E 709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. (610 mm) in diameter and greater, and inside surfaces of pipe less than 24 in. in diameter for a distance of one pipe diameter from the ends.

S6.2 Butt-weld end preparations are to be completely magnetic-particle examined in accordance with Practice E 709.

S6.3 *Acceptance Standards*, shall be by agreement between the manufacturer and the purchaser.

S7. Magnetic Particle Examinations of Weld Metal

S7.1 All accessible welds shall be examined in accordance with Practice E 709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. (610 mm) in diameter and greater, and inside surfaces of pipe less than 24 in. in diameter for a distance of one pipe diameter from the ends.

S7.2 Butt-weld end preparations are to be completely magnetic-particle examined in accordance with Practice E 709.

S7.3 *Acceptance Standards*, shall be by agreement between the manufacturer and the purchaser.

S8. Liquid Penetrant Examination of Base Metal

S8.1 All accessible surfaces of the pipe shall be examined in accordance with Test Method E 165. Accessible is as defined in S7.1.

S8.2 Butt-weld end preparations are to be completely liquid penetrant examined in accordance with Test Method E 165.

S8.3 *Acceptance Standards*, shall be by agreement between the manufacturer and the purchaser.

S9. Liquid Penetrant Examination of Weld Metal

S9.1 All accessible surfaces of the pipe shall be examined in accordance with Test Method E 165. Accessible is as defined in S6.1.

S9.2 *Acceptance Standards*, shall be by agreement between the manufacturer and the purchaser.

S10. Ultrasonic Test

S10.1 *Plate in Flat:*

S10.1.1 One hundred percent on one surface shall be scanned.

S10.1.2 Straight search shall be used in accordance with Specification A 435/A435M.

S10.1.3 Acceptance standards shall be in accordance with Specification A 435/A 435M or as by agreement between the manufacturer and the purchaser.

S11. Repair Welding

S11.1 Repair of base metal defects by welding shall be done only with customer approval.

S12. Description of Term

S12.1 *lot*—all pipe of the same mill heat of plate material and wall thickness (within ±¼ in. (6.4 mm)) heat treated in one furnace charge. For pipe that is not heat treated or that is heat treated in a continuous furnace, a lot shall consist of each 200 ft (61 m) or fraction thereof of all pipe of the same mill heat of plate material and wall thickness (within ±¼ in. (6.4 mm)), subjected to the same heat treatment. For pipe heat treated in a batch-type furnace that is automatically controlled within a 50°F (28°C) range and is equipped with recording pyrometers so that heating records are available, a lot shall be defined the same as for continuous furnaces.

Designation: A 688/A 688M – 04

Standard Specification for Welded Austenitic Stainless Steel Feedwater Heater Tubes[1]

This standard is issued under the fixed designation A 688/A 688M; 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 welded austenitic stainless steel feedwater heater tubes including those bent, if specified, into the form of U-tubes for application in tubular feed-water heaters.

1.2 The tubing sizes covered shall be ⅝ to 1 in. [15.9 to 25.4 mm] inclusive outside diameter, and average or minimum wall thicknesses of 0.028 in. [0.7 mm] and heavier.

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 shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[4]

3. Terminology

3.1 *Definitions Of Terms*—For definitions of terms used in this specification, refer to Terminology A 941.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (length or number of pieces),

4.1.2 Material description,

4.1.3 Dimensions—Outside diameter, wall thickness (minimum or average wall), and length,

4.1.4 Grade (chemical composition) (Table 1),

4.1.5 U-bend requirements, if order specifies bending, U-bend schedules or drawings shall accompany the order,

4.1.6 Optional requirements—Purchaser shall specify if annealing of the U-bends is required or whether tubes are to be hydrotested or air tested (see 11.6)

4.1.7 Supplementary requirements—Purchaser shall specify on the purchase order if material is to be eddy current tested in accordance with Supplementary Requirements S1 or S2, and if special test reports are required under Supplementary Requirement S3, and,

4.1.8 Any special requirements.

5. General Requirements

5.1 Material furnished to this specification shall conform to the applicable requirements of the latest published edition of Specification A 1016/A 1016M unless otherwise provided herein.

6. Materials and Manufacture

6.1 The tube shall be made from flat-rolled steel by an automatic welding process with no addition of filler metal.

[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.

Current edition approved Sept. 1, 2004. Published September 2004. Originally approved in 1973. Last previous edition approved in 2003 as A 688/A 688M – 03.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-688 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 Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

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

TABLE 1 Chemical Requirements

Element	Grade	TP 304	TP 304L	TP 304LN	TP 316	TP 316L	TP 316LN	TP XM-29	TP 304N	TP 316N	. . .	. . .	. . .	. . .
	UNS Designation[A]	S30400	S30403	S30453	S31600	S31603	S31653	S24000	S30451	S31651	N08367	N08926	S31254	S32654
		Composition, %												
Carbon, max		0.08	0.035	0.035	0.08	0.035	0.035	0.060	0.08	0.08	0.030	0.020	0.020	0.020
Manganese, max[B]		2.00	2.00	2.00	2.00	2.00	2.00	11.50–14.50	2.00	2.00	2.00	2.00	1.00	2.0–4.0
Phosphorus, max		0.040	0.040	0.040	0.040	0.040	0.040	0.060	0.040	0.040	0.040	0.03	0.030	0.030
Sulfur, max		0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.01	0.010	0.005
Silicon, max		0.75	0.75	0.75	0.75	0.75	0.75	1.00	0.75	0.75	1.00	0.5	0.80	0.50
Nickel		8.00–11.00	8.00–13.00	8.00–13.00	10.00–14.00	10.00–15.00	10.00–15.00	2.25–3.75	8.00–11.0	10.00–14.00	23.50–25.50	24.00–26.00	17.5–18.5	21.0–23.0
Chromium		18.00–20.00	18.00–20.00	18.00–20.00	16.00–18.00	16.00–18.00	16.00–18.00	17.00–19.00	18.0–20.0	16.0–18.0	20.00–22.00	19.00–21.00	19.5–20.5	24.0–25.0
Molybdenum		...	...	...	2.00–3.00	2.00–3.00	2.00–3.00	...	...	2.00–3.00	6.00–7.00	6.0–7.0	6.0–6.5	7.0–8.0
Nitrogen[C]		...	...	0.10–0.16	...	...	0.10–0.16	0.20–0.40	0.10–0.16	0.10–0.16	0.18–0.25	0.15–0.25	0.18–0.22	0.45–0.55
Copper		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.75 max	0.5–1.5	0.50–1.00	0.30–0.60

[A] New designation established in accordance with Practice E 527 and SAE J1086.
[B] Maximum, unless otherwise noted.
[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

6.2 Subsequent to welding and prior to final heat treatment, the tubes shall be cold worked either in both the weld and base metal, or in the weld metal only. The method of cold work may be specified by the purchaser. When cold drawn, the purchaser may specify the minimum amount of reduction in cross-sectional area or wall thickness, or both.

6.3 Many surface contaminants may have detrimental effects on high temperature properties or corrosion resistance of tubing. Contamination by copper, lead, mercury, zinc, chlorides, or sulfur may be detrimental to stainless steels. The manufacturer shall employ techniques that minimize surface contamination by these elements.

7. Cleaning Before Annealing

7.1 All lubricants of coatings used in the manufacture of straight-length tube or in the bending shall be removed from all surfaces prior to any annealing treatments. U-bends on which a lubricant had been applied to the inside surface during bending shall have the cleanness of their inside surface confirmed by blowing close fitting acetone-soaked felt plugs through 10 % of the tubes of each bend radius. Dry, oil-free, air or inert gas shall be used to blow the plugs through the tubes. If the plugs blown through any tube shows more than a light gray discoloration, all tubes that have had a lubricant applied to the inside surface during bending shall be recleaned. After recleaning 10 % of the tubes of each bend radius whose inside surface had been subjected to bending lubricants shall be retested.

8. Heat Treatment

8.1 All finished straight tubing or straight tubing ready for U-bending shall be furnished in the solution-annealed condition. The annealing procedure, except for N08367, S31254, S32654, and N08926, shall consist of heating the material to a minimum temperature of 1900 °F [1040 °C] followed by a rapid cooling to below 700 °F [370 °C]. The cooling rate shall be sufficiently rapid to prevent harmful carbide precipitation as determined in Section 13.

8.2 UNS N08367 shall be solution annealed at 2025 °F [1107 °C] minimum followed by rapid quenching.

8.3 N08926 shall be heat-treated at a minimum temperature of 2010 °F [1100 °C] followed by quenching in water or rapidly cooling by other means.

8.4 S31254 and S32654 shall be solution annealed at 2100 °F [1150 °C] minimum followed by rapid quenching.

8.5 If heat treatment of U-bends is specified, it shall satisfy the annealing procedure described above, and shall be done as follows:

8.5.1 The heat treatment shall be applied to the U-bend area plus approximately 6 in. [150 mm] of each leg beyond the tangent point of the U-bend.

8.5.2 If the heat treatment specified in 8.5 is accomplished by resistance-heating methods wherein electrodes are clamped to the tubes, the clamped areas shall be visually examined for arc burns. Burn indications shall be cause for rejection unless they can be removed by local polishing without encroaching upon minimum wall thickness.

8.5.3 Temperature control shall be accomplished through the use of optical or emission pyrometers, or both. No temperature-indicating crayons, lacquers, or pellets shall be used.

8.5.4 The inside of the tube shall be purged with a protective or an inert gas atmosphere during heating and cooling to below 700 °F [370 °C] to prevent scaling of the inside surface. The atmosphere should be noncarburizing.

9. Surface Condition

9.1 The straight tubes, after final annealing, shall be pickled using a solution of nitric and hydrofluoric acids followed by flushing and rinsing in water. If bright annealing is performed, this requirement does not apply.

9.2 A light oxide scale on the outside surface of U-bend area shall be permitted for tubes which have been electric-resistance heat treated after bending.

10. Chemical Composition

10.1 *Product Analysis*:

10.1.1 When requested in the purchase order, a product analysis shall be made by the supplier from one tube or coil of steel per heat. The chemical composition shall conform to the requirements shown in Table 1.

10.1.2 A product analysis tolerance of Specification A 480/A 480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04 % or less.

10.1.3 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests, for the elements in question, shall meet the requirements of this specification; otherwise all remaining material in the heat or lot (Note 1) shall be rejected, or at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes that do not meet the requirements of this specification shall be rejected.

NOTE 1—For flattening and flange requirements, the term "lot" applies to 125 tube groupings, prior to cutting to length, of the same nominal size and wall thickness, produced from the same heat of steel and annealed in a continuous furnace.

11. Mechanical Requirements

11.1 *Tensile Properties*:

11.1.1 The material shall conform to the tensile properties shown in Table 2.

11.1.2 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 (Note 2).

11.2 *Hardness*:

11.2.1 Grade TP XM-29 tubes shall have a hardness number not exceeding 100 HRB or its equivalent. Tubes of all other grades shall have a hardness number not exceeding 90 HRB or its equivalent. This hardness requirement is not to apply to the bend area of U-bend tubes which are not heat treated after bending.

11.2.2 Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot.

NOTE 2—For tension, hardness, and corrosion test requirements, the term "lot" applies to all tubes prior to cutting to length, of the same nominal diameter and wall thickness, produced from the same heat of steel and annealed in a continuous furnace at the same temperature, time at heat, and furnace speed.

11.3 *Reverse Bend Test*:

11.3.1 One reverse bend test shall be made on a specimen from each 1500 ft [460 m] of finished tubing.

11.3.2 A section 4 in. [100 mm] minimum in length shall be split longitudinally 90° on each side of the weld. The sample shall then be opened and bent around a mandrel with a maximum thickness of four times the wall thickness, with the mandrel parallel to the weld and against the original outside surface of the tube. The weld shall be at the point of maximum bend. There shall be no evidence of cracks, or of overlaps resulting from the reduction in thickness of the weld area by cold working. When the geometry or size of the tubing make it difficult to test the sample as a single piece, the sample may be sectioned into smaller pieces provided a minimum of 4 in. of weld is subjected to reverse bending.

NOTE 3—The reverse bend test is not applicable when specified wall is 10 % or more of the specified outside diameter, or the wall thickness is 0.134 in. [3.4 mm] or greater, or the outside diameter size is less than 0.375 in. [9.5 mm]. Under these conditions, the reverse flattening test of Specification A 1016/A 1016M shall apply.

11.4 *Flattening Test*—Flattening tests shall be made on specimens from each end of one finished tube, not the one used for the flange test, from each lot (Note 1).

11.5 *Flange Test*—Flange tests shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

11.6 *Pressure Test*:

11.6.1 Each straight tube or each U-tube after completion of the bending and post-bending heat treatment, shall be pressure tested in accordance with one of the following paragraphs as specified by the purchaser.

11.6.1.1 *Hydrostatic Test*—Each tube shall be given an internal hydrostatic test in accordance with Specification A 1016/A 1016M, except that the test pressure and hold time, when other than that stated in Specification A 1016/A 1016M, shall be agreed upon between purchaser and manufacturer.

11.6.1.2 *Air Underwater Test*—Each tube shall be air underwater tested in accordance with Specification A 1016/A 1016M.

12. Nondestructive Test (Electric Test)

12.1 Each straight tube shall be tested after the finish heat treatment by passing it through a nondestructive tester capable of detecting defects on the entire cross section of the tube, in accordance with Specification A 1016/A 1016M.

TABLE 2 Tensile Requirements

Grade	304, 316	304L, 316L	XM-29	304N, 316N	304LN, 316LN	. . .	. . .	. . .	. . .	. . .	. . .
UNS Designation	S30400, S31600	S30403, S31603	S24000	S30451, S31651	S30453, S31653	N08367 t ≤ 0.187	N08367 t > 0.187	N08926	S31254 t ≤ 0.187	S31254 t > 0.187	S32654
Tensile strength, min ksi [MPa]	75 [515]	70 [485]	100 [690]	80 [550]	75 [515]	100 [690]	95 [655]	94 [650]	100 [690]	95 [655]	120 [825]
Yield strength, min ksi [MPa]	30 [205]	25 [175]	55 [380]	35 [240]	30 [205]	45 [310]	45 [310]	43 [295]	45 [310]	45 [310]	65 [450]
Elongation in 2 in. or 50 mm, min, %	35	35	35	35	35	30	30	35	35	35	40

13. Corrosion Resisting Properties

13.1 One full section sample 1 in. [25.4 mm] long from the center of a sample tube of the smallest radius bend which is heat treated shall be tested in the heat treated condition in accordance with Practices A 262.

13.2 One full-section sample 1 in. [25.4 mm] long from each lot (Note 2) of straight tubes shall be tested in the finished condition in accordance with Practices A 262.

13.3 The appearance of any fissures or cracks in the test specimen when evaluated in accordance with Practices A 262 indicating the presence of intergranular attack, shall be cause for rejection of that lot.

14. Permissible Variations in Dimensions (Fig. 1)

14.1 Permissible variations from the specified outside diameter shall be in accordance with Specification A 1016/A 1016M. Those tolerances do not apply to the bent portion of the U-tubes. At the bent portion of a U-tube for $R = 2 \times D$ or greater, neither the major nor minor diameter of the tube shall deviate from the nominal diameter prior to bending by more than 10 %. If less than $2 \times D$ is specified, tolerances could be greater.

14.2 *Permissible Variations from the Specified Wall Thickness*:

14.2.1 Permissible variations from the specified minimum wall thickness shall not exceed +20 % − 0.

14.2.2 Permissible variations from the specified average wall thickness are ±10 % of the nominal wall thickness.

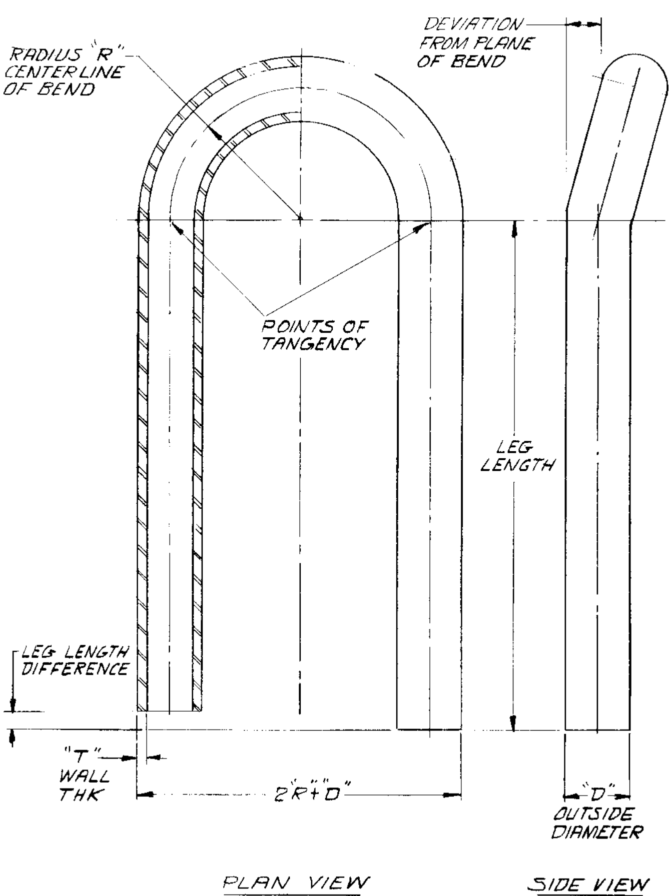

FIG. 1 Plane Bend for U-Tube

14.2.3 The wall thickness of the tube in the U-bent section shall not be less than value determined by the equation:

$$t_f = \frac{4RT}{4R + D}$$

where:

t_f = wall thickness after bending, in. [mm],
T = minimum wall thickness of 14.2.1 or 14.2.2, in. [mm],
R = centerline bend radius, in. [mm], and
D = nominal outside tube diameter, in. [mm].

14.3 *Permissible Variations from the Specified Length*:

14.3.1 *Straight Lengths*—The maximum permissible variations for lengths 24 ft [7.3 m] and shorter shall be +⅛ in. [3 mm], −0; for lengths longer than 24 ft [7.3 mm], an additional over tolerance of +⅛ in. [3 mm] for each 10 ft [3 m], or fraction thereof, shall be permitted up to a maximum of +½ in. [13 mm].

14.3.2 *U-Bends*—In the case of U-tubes, the length of the tube legs as measured from the point of tangency of the bend and the tube leg to the end of the tube leg, shall not be less than specified, but may exceed the specified values by the amount given in Table 3. The difference in lengths of the tube legs shall not be greater than ⅛ in. unless otherwise specified.

14.4 The end of any tube may depart from square by not more than the amount given in Table 4.

14.5 The leg spacing measured between the points of tangency of the bend to the legs shall not vary from the value (2 R − specified tube outside diameter) by more than 1⁄16 in. [1.5 mm] where R is the center-line bend radius.

14.6 The bent portion of the U-tube shall be substantially uniform in curvature, and not to exceed ± 1⁄16 in. [1.5 mm] of the nominal center-line radius.

14.7 Permissible deviation from the plane of bend (Fig. 1) shall not exceed 1⁄16 in. [1.5 mm] as measured from the points of tangency.

15. Workmanship, Finish, and Appearance

15.1 Tubing purchased to this specification is intended for use in heat exchangers, and will be inserted through close-fitting holes in baffles or support plates, or both, spaced along the tube length. The tube ends will also be inserted into very close-fitting holes in a tubesheet and expanded and may be welded therein. The tubes shall be able to stand expanding and bending without showing cracks and flaws, and shall be finished reasonably straight and suitable for the intended purpose.

15.2 The residual chloride salt contamination of the inside and outside surface of the tubing at the time of packing for shipment from the mill shall not exceed a concentration of 1 mg/ft^2 [10.7 mg/m^2] of tube surface. One tube in each five hundred pieces shall be checked immediately prior to packing

TABLE 3 Tube Leg Length Tolerance

Leg Length, ft [m]	Plus Tolerance, in. [mm]
Up to 20 [6], incl	⅛ [3.2]
Over 20 to 30 [6 to 9], incl	5⁄32 [4.0]
Over 30 to 40 [9 to 12.2], incl	3⁄16 [4.8]

TABLE 4 Squareness of Ends Tolerance

Tube OD, in. [mm]	Tolerance, in. [mm]
⅝ [15.9], incl	0.010 [0.25]
Over ⅝ to 1 in. [15.9 to 25.4], incl	0.016 [0.4]

for shipment for chloride salt contamination by a procedure agreed upon by the manufacturer and purchaser.

16. Inspection

16.1 The inspector representing the purchaser shall have entry, at all times, to those areas where inspection and testing is being performed on the purchaser's ordered material. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

17. Rejection

17.1 Each length of tubing received from the manufacturer may be inspected by the purchaser, and, if it does not meet the requirements of the specification based on the inspection and test method outlined in the specification, the tubing may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

17.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective, shall be set aside, and the manufacturer shall be notified. Disposition of such material shall be a matter for agreement between the manufacturer and the purchaser.

18. Certification

18.1 A test report, signed by an authorized employee or representative of the manufacturer, shall be furnished to the purchaser to indicate the specification and grade, the results of the heat analysis, hardness and tensile properties. Product analysis will be reported only when requested on the purchase order as provided in 4.1.7.

19. Product Marking

19.1 All tubes shall be marked with the heat number.

19.2 Containers and packages shall be marked or tagged to show the purchaser's order number, the manufacturer's order number, specification, grade, size and gage of tubing, number of pieces contained in the package, and item number (if appropriate).

20. Packaging

20.1 All tubing shall be packaged and blocked in such a manner as to prevent damage in ordinary handling and transportation. The boxes shall be constructed in such a manner that no nails, staples, screws, or similar fasteners are required to close and secure the box after the tubes have been placed in the box. The box shall be lined with plastic sheet or vapor barrier materials so as to prevent chloride contamination of the tube during handling, transportation, and storage.

20.2 The U-bent tubes shall be arranged in boxes so that the smaller radius bends may be removed without disturbing larger radius bends. Tubes for an item number shall be boxed together.

21. Keywords

21.1 austenitic stainless steel; feedwater heater tubes; stainless steel tube; steel tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement or requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order, in which event the necessary tests shall be made by the manufacturer prior to the bending or shipment of the tubing.

S1. Nondestructive Eddy-Current Test

S1.1 Each tube in the finished condition, except for bending if that is required, shall be tested by passing it through an electric nondestructive tester capable of detecting defects on the entire cross section of the tube. Suitable instrumentation shall be used to clearly distinguish the artificial defects. The outside and inside surfaces of the tubes shall be free of loose scale, metallic particles, or other material which would tend to restrict signals or create electrical noise. The tubing shall be inspected by feeding it longitudinally through an inspection coil or coils with a diameter suitable for the diameter of tubing to be inspected. The instrument calibration shall be accomplished with a reference standard prepared from an appropriate length of selected tubing of the same size, grade, and physical condition as the material to be inspected. The standard shall be fed through the coil at the same speed at which the inspection of the tubing is performed.

S1.2 The factors listed in S1.3 shall be selected or adjusted, or both, in accordance with the instrument manufacturer's instructions, for the particular instrument involved as required to achieve optimum instrument distinction between the reference defects and plain portions of the tube.

S1.3 The following as well as other factors involved shall not be used in such a manner that they detract from the overall ability of the instrument to detect defects: test frequency, direct-current saturation level, filter networks, phase-analysis circuits, coil diameter, and instrument gain.

S1.4 The reference standard shall consist of a defect-free sample of the same size, alloy, and condition (temper) as that being tested, and shall contain longitudinal and circumferential notches on the outside diameter establishing the rejection level of the tubing to be tested. Inside diameter notches, both longitudinal and transverse, shall also be a part of the reference standard. These inside notches may be larger than the outside notches, and are intended for use only to assure instrument phase settings capable of yielding optimum inside surface sensitivity.

S1.4.1 All notches shall be produced by EDM methods. The outside diameter notches shall be of the dimensions shown in Table S1.1 and Fig. S1.1.

S1.5 All tubing shall meet this specification. The instrument calibration shall be verified at the start of testing, after any shut down of the test equipment, after any test equipment adjustment, or at least every ½ h of continuous production testing or both. Tubes generating a signal above the outside diameter calibration standard sensitivity level shall be rejected.

S1.6 Tubes may be reconditioned and retested provided reconditioning does not adversely effect the minimum wall thickness or other properties of the tube specification requirements. Upon agreement between purchaser and manufacturer, the referee method, employing ultrasonic testing, may be employed for retesting tubes rejected by the eddy-current test. The calibration standard for this test shall be identical to that required for the eddy-current test.

S2. Nondestructive Eddy-Current Testing (Select Commercial Grade)

S2.1 The manufacturer shall test the tubing using the procedure outlined in Supplementary Requirement S1, except for the notch standards, which shall be as indicated in Table S2.1.

TABLE S1.1 Notch Depth

OD, in. [mm]	Wall, in. [mm]	Depth^A, in. [mm]	Length, max, in. [mm]	Width, max
⅝ to 1 [15.9 to 25.4], incl	0.028 [0.7] and heavier	0.0045 [0.11] or 10 % of wall thickness which-ever is greater	0.375 [9.5]	wall thickness but not greater than 0.062 in. [1.6 mm]

^A The tolerance of notch depth shall be ±8 % or ±0.0005 in. [0.01 mm], whichever is greater. Refer to Fig. S1.1 for notch location orientation and length of calibration standard.

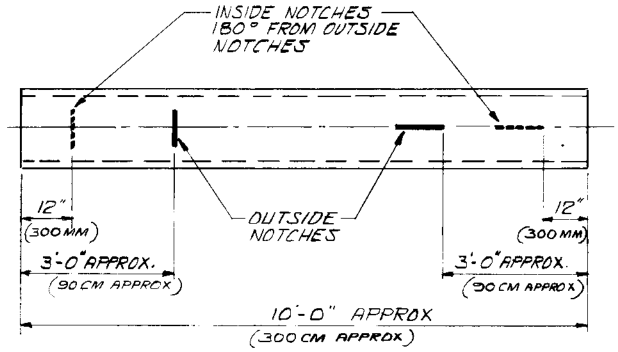

FIG. S1.1 Eddy-Current Test Standard

TABLE S2.1 Notch Depth for Select Commercial Grade

OD, in. [mm]	Wall, in. [mm]	Depth, in. [mm]	Length, max, in. [mm]	Width, max
⅝ to 1 [15.9 to 25.4], incl	0.035 [0.9] and heavier	0.0045 [0.11] or 10 % of wall thickness, which-ever is greater	0.375 [9.5]	3 times notch depth
⅝ to 1 [15.9 to 25.4], incl	less than 0.035 [0.9]	0.0045 [0.11] or 10 % of wall thickness, which-ever is greater	0.375 [9.5]	wall thickness

S3. Report

S3.1 A report shall be furnished by the manufacturer to include a record of all tests performed to qualify material to this specification. This record shall include numbers of tests performed and qualitative or quantitative results as is applicable.

S4. Intergranular Corrosion Tests

S4.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S4.1—Practice E requires testing on the sensitized condition for low carbon grades, and on the as-shipped condition for other grades.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 688/A 688M – 03, which may impact the use of this specification. (Approved September 1, 2004)

(*1*) Revised heat treat temperatures of S31254 and S32654.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 688/A 688M – 02, which may impact the use of this specification. (Approved September 10, 2003)

(*1*) Clarified ordering requirements to include purchaser's responsibilities in Section 4.

Designation: A 672 – 06

Standard Specification for Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures[1]

This standard is issued under the fixed designation A 672; 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 steel pipe: electric-fusion-welded with filler metal added, fabricated from pressure-vessel quality plate of any of several analyses and strength levels and suitable for high-pressure service at moderate temperatures. Heat treatment may or may not be required to attain the desired properties or to comply with applicable code requirements. Supplementary requirements are provided for use when additional testing or examination is desired.

1.2 The specification nominally covers pipe 16 in. (405 mm) in outside diameter or larger with wall thicknesses up to 3 in. (75 mm), inclusive. Pipe having other dimensions may be furnished provided it complies with all other requirements of this specification.

1.3 Several grades and classes of pipe are provided.

1.3.1 *Grade* designates the type of plate used.

1.3.2 *Class* designates the type of heat treatment performed during manufacture of the pipe, whether the weld is radiographically examined, and whether the pipe has been pressure tested as listed in 1.3.3.

1.3.3 Class designations are as follows (Note 1):

Class	Heat Treatment on Pipe	Radiography, see Section	Pressure Test, see Section
10	none	none	none
11	none	9	none
12	none	9	8.3
13	none	none	8.3
20	stress relieved, see 5.3.1	none	none
21	stress relieved, see 5.3.1	9	none
22	stress relieved, see 5.3.1	9	8.3
23	stress relieved, see 5.3.1	none	8.3
30	normalized, see 5.3.2	none	none
31	normalized, see 5.3.2	9	none
32	normalized, see 5.3.2	9	8.3
33	normalized, see 5.3.2	none	8.3
40	normalized and tempered, see 5.3.3	none	none
41	normalized and tempered, see 5.3.3	9	none
42	normalized and tempered, see 5.3.3	9	8.3
43	normalized and tempered, see 5.3.3	none	8.3
50	quenched and tempered, see 5.3.4	none	none
51	quenched and tempered, see 5.3.4	9	none
52	quenched and tempered, see 5.3.4	9	8.3
53	quenched and tempered, see 5.3.4	none	8.3

NOTE 1—Selection of materials should be made with attention to temperature of service. For such guidance, Specification A 20/A 20M may be consulted.

1.4 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates
A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates
A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications
E 109 Method for Dry Powder Magnetic Particle Inspection[4]
E 138 Method for Wet Magnetic Particle Inspection[4]
E 110 Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers
E 165 Test Method for Liquid Penetrant Examination
E 709 Guide for Magnetic Particle Examination

2.1.1 *Plate Steel Specifications (Table 1)*

A 202/A 202M Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Manganese-Silicon[4]
A 204/A 204M Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum
A 285/A 285M Specification for Pressure Vessel Plates,

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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 A01.09 on Carbon Steel Tubular Products.

Current edition approved May 1, 2006. Published May 2006. Originally approved in 1972. Last previous edition approved in 2005 as A 672 – 96 (2005).

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-672 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] Withdrawn.

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

Carbon Steel, Low- and Intermediate-Tensile Strength
A 299/A 299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon
A 302/A 302M Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel
A 515/A 515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
A 516/A 516M Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
A 533/A 533M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum and Manganese-Molybdenum-Nickel
A 537/A 537M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel

2.2 *ASME Boiler and Pressure Vessel Code:*[5]
Section II, Material Specifications
Section III, Nuclear Vessels
Section VIII, Unfired Pressure Vessels
Section IX, Welding Qualifications

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 A *lot* shall consist of 200 ft (61 m) or fraction thereof of pipe from the same heat of steel.

3.1.2 The description of a lot may be further restricted by use of Supplementary Requirement S14.

4. Ordering Information

4.1 The inquiry and order for material under this specification should include the following information:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (steel pipe, electric-fusionwelded),

4.1.3 Specification number,

4.1.4 Grade and class designations (see 1.3),

4.1.5 Size (inside or outside diameter, nominal or minimum wall thickness),

4.1.6 Length (specific or random),

4.1.7 End finish (11.4),

4.1.8 Purchase options, if any (see 5.2.3, 11.3, 14.1 and Sections 16, 20.1, 21, 22 of Specification A 530/A 530M), and

4.1.9 Supplementary requirements, if any, (refer to S1 through S14).

5. Materials and Manufacture

5.1 *Materials*—The steel plate material shall conform to the requirements of the applicable plate specification for pipe grade ordered as listed in Table 1.

5.2 *Welding*:

5.2.1 The joints shall be double-welded, full-penetration welds made in accordance with procedures and by welders or welding operators qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

5.2.2 The welds shall be made either manually or automatically by an electric process involving the deposition of filler metal.

5.2.3 The welded joint shall have positive reinforcement at the center of each side of the weld, but not more than ⅛ in. (3.2 mm). This reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be smooth, and the deposited metal shall be fused smoothly and uniformly into the plate surface.

5.2.4 When radiographic examination in accordance with 9.1 is to be used, the weld reinforcement shall be governed by the more restrictive provisions of UW–51 of Section VIII of the ASME Boiler and Pressure Vessel Code instead of 5.2.3 of this specification.

TABLE 1 Plate Specification

Pipe Grade	Type of Steel	ASTM Specification	
		No.	Grade
A 45	plain carbon	A 285/A 285M	A
A 50	plain carbon	A 285/A 285M	B
A 55	plain carbon	A 285/A 285M	C
B 55	plain carbon, killed	A 515/A 515M	55
B 60	plain carbon, killed	A 515/A 515M	60
B 65	plain carbon, killed	A 515/A 515M	65
B 70	plain carbon, killed	A 515/A 515M	70
C 55	plain carbon, killed, fine grain	A 516/A 516M	55
C 60	plain carbon, killed, fine grain	A 516/A 516M	60
C 65	plain carbon, killed, fine grain	A 516/A 516M	65
C 70	plain carbon, killed, fine grain	A 516/A 516M	70
D 70	manganese-silicon—normalized	A 537/A 537M	1
D80	manganese-silicon—Q&T[A]	A 537/A 537M	2
H 75	manganese-molybdenum—normalized	A 302/A 302M	A
H 80	manganese-molybdenum—normalized	A 302/A 302M	B, C or D
J 80	manganese-molybdenum—Q&T[A]	A 533/A 533M	Cl-1[B]
J 90	manganese-molybdenum—Q&T[A]	A 533/A 533M	Cl-2[B]
J 100	manganese-molybdenum—Q&T[A]	A 533/A 533M	Cl-3[B]
K 75	chromium-manganese-silicon	A 202/A 202M	A
K 85	chromium-manganese-silicon	A 202/A 202M	B
L 65	molybdenum	A 204/A 204M	A
L 70	molybdenum	A 204/A 204M	B
L 75	molybdenum	A 204/A 204M	C
N 75	manganese-silicon	A 299/A 299M	. . .

[A] Q&T = quenched and tempered.
[B] Any grade may be furnished.

5.3 *Heat Treatment*—All classes other than 10, 11, 12 and 13 shall be heat treated in furnace controlled to ± 25 °F (14 °C) and equipped with a recording pyrometer so that heating records are available. Heat treating after forming and welding shall be to one of the following:

5.3.1 Classes 20, 21, 22, and 23 pipe shall be uniformly heated within the post-weld heat-treatment temperature range

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

indicated in Table 2 for a minimum of 1 h/in. of thickness or 1 h, whichever is greater.

5.3.2 Classes 30, 31, 32, and 33 pipe shall be uniformly heated to a temperature in the austenitizing range and not exceeding the maximum normalizing temperature indicated in Table 2 and subsequently cooled in air at room temperature.

5.3.3 Classes 40, 41, 42, and 43 pipe shall be normalized in accordance with 5.3.2. After normalizing, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at temperature for a minimum of ½ h/in. of thickness or ½ h, whichever is greater, and air cooled.

5.3.4 Classes 50, 51, 52, and 53 pipe shall be uniformly heated to a temperature in the austenitizing range, and not exceeding the maximum quenching temperature indicated in Table 2 and subsequently quenched in water or oil. After quenching the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at temperature for a minimum of ½ h/in. of thickness or ½ h, whichever is greater, and air cooled.

6. General Requirements

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

7. Chemical Composition

7.1 *Product Analysis of Plate*—The pipe manufacturer shall make an analysis of each mill heat of plate material. The product analysis so determined shall meet the requirements of the plate specification to which the material was ordered.

7.2 *Product Analysis of Weld*—The pipe manufacturer shall make an analysis of the finished deposited weld material from each 500 ft (152 m) or fraction thereof. Analysis shall conform to the welding procedure for deposited weld metal.

7.3 Analysis may be taken from the mechanical test specimens. The results of the analyses shall be reported to the purchaser.

7.4 If the analysis of one of the tests specified in 7.1 or 7.2 does not conform to the requirements specified, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the requirements specified. Nonconforming pipe shall be rejected.

8. Mechanical Properties

8.1 *Tension Test*:

8.1.1 *Requirements*—Transverse tensile properties of the welded joint shall meet the minimum requirements for ultimate tensile strength of the specified plate material. In addition for Grades Dxx, Hxx, Jxx, and Nxx in Classes 3x, 4x, and 5x transverse tensile properties of the base plate, shall be determined on specimens cut from the heat-treated pipe. These properties shall meet the mechanical test requirements of the plate specification.

8.1.2 *Number of Tests*—One test specimen shall be made to represent each lot of finished pipe.

8.1.3 *Test Specimen Location and Orientation*—The test specimens shall be taken transverse to the weld at the end of the finished pipe and may be flattened cold before final machining to size.

8.1.4 *Test Method*—The test specimen shall be made in accordance with QW-150 in Section IX of the ASME Boiler and Pressure Vessel Code. The test specimen shall be tested at room temperature in accordance with Test Methods and Definitions A 370.

8.2 *Transverse-Guided-Weld-Bend Tests*:

8.2.1 *Requirements*—The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. (3.2 mm) in any direction are present in the weld metal or between the weld and the base metal after bending. Cracks that originate along the edges of the specimen during testing, and that are less than ¼ in. (6.4 mm) measured in any direction shall not be considered.

8.2.2 *Number of Tests*—One test (two specimens) shall be made to represent each lot of finished pipe.

8.2.3 *Test Specimen Location and Orientation*—Two bend test specimens shall be taken transverse to 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 as the pipe, the test plate being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

8.2.4 *Test Method*—The test requirements of Test Methods and Definitions A 370, paragraph A2.5.1.7 shall be met. For wall thickness over ⅜ in. (9.5 mm) but less than ¾ in. (19.0 mm) side-bend tests may be made instead of the face and root-bend tests. For wall thicknesses ¾ in. and over both specimens shall be subjected to the side-bend test.

8.3 *Pressure Test*—Classes X2 and X3 pipe shall be tested in accordance with Specification A 530/A 530M, Section 20.

9. Radiographic Examination

9.1 The full length of each weld of Classes X1 and X2 shall be radiographically examined in accordance with and meet the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, paragraph UW–51.

9.2 Radiographic examination may be performed prior to heat treatment.

10. Rework

10.1 *Elimination of Surface Imperfections*—Unacceptable surface imperfections shall be removed by grinding or machining. The remaining thickness of the section shall be no less than the minimum specified in Section 11. The depression after grinding or machining shall be blended uniformly into the surrounding surface.

10.2 *Repair of Base Metal Defects by Welding*:

10.2.1 The manufacturer may repair, by welding, base metal where defects have been removed, provided the depth of the repair cavity as prepared for welding does not exceed ⅓ of the nominal thickness and the requirements of 10.2.2-10.2.6 are met. Base metal defects in excess of these may be repaired with proper approval of the customer.

TABLE 2 Heat Treatment Parameters

Pipe Grade[A]	Specification and Grade[B]	Post-Weld Heat-Treat Temperature Range, °F (°C)	Normalizing Temperature, max, °F (°C)	Quenching Temperature, max, °F (°C)	Tempering Temperature, min, °F (°C)
A 45	A 285A	1100–1250 (590–680)	1700 (925)	. . .	. . .
A 50	A 285B	1100–1250 (590–680)	1700 (925)	. . .	. . .
A 55	A 285C	1100–1250 (590–680)	1700 (925)	. . .	. . .
B 55	A 515-55	1100–1250 (590–680)	1750 (950)	. . .	. . .
B 60	A 515-60	1100–1250 (590–680)	1750 (950)	. . .	. . .
B 65	A 515-65	1100–1250 (590–680)	1750 (950)	. . .	. . .
B 70	A 515-70	1100–1250 (590–680)	1750 (950)	. . .	. . .
C 55	A 516-55	1100–1250 (590–680)	1700 (925)	1650 (900)	1200 (650)
C 60	A 516-60	1100–1250 (590–680)	1700 (925)	1650 (900)	1200 (650)
C 65	A 516-65	1100–1250 (590–680)	1700 (925)	1650 (900)	1200 (650)
C 70	A 516-70	1100–1250 (590–680)	1700 (925)	1650 (900)	1200 (650)
D 70	A 537-1	1100–1250 (590–680)	1700 (925)	. . .	. . .
D 80	A 537-2	1100–1250 (590–680)	. . .	1650 (900)	1200 (650)
H 75	A 302-A	1100–1250 (590–680)	1800 (980)	. . .	1100 (590)
H 80	A 302-B, C or D	1100–1250 (590–680)	1800 (980)	. . .	1100 (590)
J 80	A 533-C11[B]	1100–1250 (590–680)	. . .	1800 (980)	1100 (590)
J 90	A 533-C12[B]	1100–1250 (590–680)	. . .	1800 (980)	1100 (590)
J 100	A 533-C13[B]	1100–1250 (590–680)	. . .	1800 (980)	1100 (590)
K 75	A 202A	1100–1200 (590–650)	. . .	. . .	. . .
K 85	A 202B	1100–1200 (590–650)	. . .	. . .	. . .
L 65	A 204A	1100–1200 (590–650)	. . .	. . .	. . .
L 70	A 204B	1100–1200 (590–650)	. . .	. . .	. . .
L 75	A 204C	1100–1200 (590–650)	. . .	. . .	. . .
N 75	A 299	1100–1200 (590–650)	1700 (925)	. . .	. . .

[A] Numbers indicate minimum tensile strength in ksi.
[B] Any grade may be used.

10.2.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair welding.

10.2.3 The welding procedure and welders or welding operators are to be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10.2.4 The full length of the repaired pipe shall be heat treated after repair in accordance with the requirements of the pipe class specified.

10.2.5 Each repair weld of a defect where the cavity, prepared for welding, has a depth exceeding the lesser of ⅜ in. (9.5 mm) or 10 % of the nominal thickness shall be examined by radiography in accordance with the methods and the acceptance standards of Section 9.

10.2.6 The repair surface shall be blended uniformly into the surrounding base metal surface and examined and accepted in accordance with Section S6 or S8.

10.3 *Repair of Weld Metal Defects by Welding*:

10.3.1 The manufacturer may repair weld metal defects if he meets the requirements of 10.2.3, 10.2.4, 10.3.2, 10.3.3, and 10.4.

10.3.2 The defects shall be removed by suitable mechanical or thermal cutting or gouging methods and the repair cavity examined and accepted in accordance with Sections S7 or S9.

10.3.3 The weld repair shall be blended uniformly into the surrounding metal surfaces and examined and accepted in accordance with 9.1 and Sections S7 or S9.

10.4 *Retest*—Each length of repaired pipe of a class requiring a pressure test shall be hydrostatically tested following repair.

11. Dimensions, Mass and Permissible Variations

11.1 The wall thickness and weight for welded pipe furnished to this specification shall be governed by the requirements of the specification to which the manufacturer ordered the plate.

11.2 Permissible variations in dimensions at any point in a length of pipe shall not exceed the following:

11.2.1 *Outside Diameter*—Based on circumferential measurement ± 0.5 % of the specified outside diameter.

11.2.2 *Out-of-Roundness*—Difference between major and minor outside diameters, 1 %.

11.2.3 *Alignment*—Using a 10-ft (3-m) straightedge placed so that both ends are in contact with the pipe, ⅛ in. (3.2 mm).

11.2.4 *Thickness*—The minimum wall thickness at any point in the pipe shall not be more than 0.01 in. (0.3 mm) under the specified nominal thickness.

11.3 Circumferential welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

11.4 Lengths with unmachined ends shall be within −0, +½ in. (−0, +13 mm) of that specified. Lengths with machined ends shall be as agreed upon between the manufacturer and the purchaser.

12. Workmanship, Finish, and Appearance

12.1 The finished pipe shall be free of injurious defects and shall have a workmanlike finish. This requirement is to mean the same as the identical requirement that appears in Specification A 20/A 20M with respect to steel plate surface finish.

13. Product Marking

13.1 In addition to the marking provision of Specification A 530/A 530M, class marking in accordance with 1.3.3 shall follow the grade marking; for example, C 70–10.

13.2 *Bar Coding*—In addition to the requirements in 13.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Tension and Bend Tests

S1.1 Tension tests in accordance with 8.1 and bend tests in accordance with 8.2 shall be made on specimens representing each length of pipe.

S2. Charpy V-Notch Test (For pipe with nominal wall thickness of ½ in. and greater)

S2.1 *Requirements*—The acceptable test energies shall be as shown in Table A1.15 of Specification A 20/A 20M for the applicable plate specification unless otherwise stated in the order. As an alternative, the test temperature may be 10 °F (−12 °C).

S2.2 *Number of Specimens*—Each test shall consist of at least three specimens.

S2.2.1 One base-metal test shall be made from one pipe length per heat, per heat-treat charge, and per nominal wall thickness. For pipe from Classes 10, 11, 12, and 13, one base metal test shall be made per heat per size and per wall thickness.

S2.2.2 One weld-metal and one heat-affected zone (HAZ) metal test shall be made in accordance with NB 4335 of Section III of the ASME Boiler and Pressure Vessel Code.

S2.3 *Test Specimen Location and Orientation:*

S2.3.1 Base-metal specimens of stress-relieved, normalized, and normalized and tempered pipe shall be taken in accordance with the provisions for tension specimens in the body of this specification.

S2.3.2 Base-metal specimens of quenched and tempered pipe shall be taken in accordance with the provisions of NB 2225 of Section III of the ASME Boiler and Pressure Vessel Code.

S3. Hardness Test

S3.1 Hardness measurements in accordance with Test Methods and Definitions A 370 or Test Method E 110 shall be made across the welded joint at both ends of each length of pipe. The maximum acceptable hardness shall be as agreed upon between the manufacturer and the purchaser.

S4. Product Analysis

S4.1 Product analyses in accordance with 7.1 shall be made on each 500 ft (152 m) of pipe or fraction thereof or alternatively, on each length of pipe as designated in the order.

S5. Metallography

S5.1 The manufacturer shall furnish one photomicrograph to show the microstructure of 100× magnification of the weld metal or base metal of the pipe in the as-finished condition. The purchaser shall state in the order: the material, base metal or weld, and the number and locations of tests to be made. This test is for information only.

S6. Magnetic Particle Examination of Base Metal

S6.1 All accessible surfaces of the pipe shall be examined in accordance with Methods E 109 or E 138. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. (610 mm) in diameter and greater, and inside surfaces of pipe less than 24 in. in diameter for a distance of one pipe diameter from the ends.

S6.2 *Acceptance Standards*—The following relevant indications are unacceptable:

S6.2.1 Any linear indications greater than 1⁄16 in. (1.6 mm) long for materials less than 5⁄8 in. (15.9 mm) thick; greater than 1⁄8 in. (3.2 mm) long for materials 5⁄8 in. thick to under 2 in. (50.8 mm) thick; and greater than 3⁄16 in. (4.8 mm) long for materials 2 in. thick or greater.

S6.2.2 Rounded indications with dimensions greater than 1⁄8 in. (3.2 mm) for thicknesses less than 5⁄8 in. (15.9 mm) and greater than 3⁄16 in. (4.8 mm) for thicknesses 5⁄8 in. and greater.

S6.2.3 Four or more indications in any line separated by 1⁄16 in. (1.6 mm) or less edge-to-edge.

S6.2.4 Ten or more indications in any 6 in.^{2} (39 cm^2) of surface with the major dimension of this area not to exceed 6 in. (152 mm) when it is taken in the most unfavorable orientation relative to the indications being evaluated.

S7. Magnetic Particle Examination of Weld Metal

S7.1 All accessible weld shall be examined in accordance with Practice E 709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe less than 24 in. (610 mm) in diameter for a distance of one pipe diameter from the ends.

S7.2 *Acceptance Criteria*—The following relevant indications are unacceptable:

S7.2.1 Any cracks and linear indications.

S7.2.2 Rounded indications with dimensions greater than 3⁄16 in. (4.8 mm).

S7.2.3 Four or more indications in any line separated 1⁄16 in. (1.6 mm) or less edge-to-edge.

S7.2.4 Ten or more indications in any 6 in.^{2} (39 cm^2) of surface with the major dimension of this area not to exceed 6 in. (152 mm) when it is taken in the most unfavorable orientation relative to the indications being evaluated.

S8. Liquid Penetrant Examination of Base Metal

S8.1 All accessible surfaces of the pipe shall be examined in accordance with Test Method E 165. Accessible is as defined in S6.1.

S8.2 The acceptance criteria shall be in accordance with S6.2.

S9. Liquid Penetrant Examination of Weld Metal

S9.1 All accessible surfaces of the pipe shall be examined in accordance with Test Method E 165. Accessible is as defined in S7.1

S9.2 The acceptance criteria shall be in accordance with S7.2

S10. Straight Beam Ultrasonic Examination of Flat Plate—UT 1

S10.1 The plate shall be examined and accepted in accordance with Specification A 435/A 435M except that 100 % of one surface shall be scanned by moving the search unit in parallel paths with not less than 10 % overlap.

S11. Straight Beam Ultrasonic Examination of Flat Plate—UT 2

S11.1 The plate shall be examined in accordance with Specification A 578/A 578M except that 100 % of one surface shall be scanned and the acceptance criteria shall be as follows:

S11.2 Any area, where one or more discontinuities produce a continuous total loss of back reflection accompanied by continuous indications on the same plane that cannot be encompassed within a circle whose diameter is 3 in. (76.2 mm) or ½ of the plate thickness, whichever is greater, is unacceptable. In addition, two or more discontinuities on the same plane and having the same characteristics but smaller than described above shall be unacceptable unless separated by a minimum distance equal to the largest diameter of the larger discontinuity or unless they may be collectively encompassed by the circle described above.

S12. Angle-Beam Ultrasonic Examination (Plate Less than 2 in. (50.8 mm) Thick)—UT 3

S12.1 The plate shall be examined in accordance with Specification A 577/A 577M except that the calibration notch shall be V-shaped and the acceptance criteria shall be as follows: Any area showing one or more reflectors producing indications whose amplitude exceeds that of the calibration notch is unacceptable.

S13. Repair Welding

S13.1 Repair of base metal defects by welding shall be done only with customer approval.

S14. Description of Term

S14.1 *lot*—all pipe of the same mill heat of plate material and wall thickness (within ±¼ in. (6.4 mm)) heat treated in one furnace charge. For pipe that is not heat treated or that is heat treated in a continuous furnace, a lot shall consist of each 200 ft (61 m) or fraction thereof of all pipe of the same mill heat of plate material and wall thickness (within ±¼ in. (6.4 mm)), subjected to the same heat treatment. For pipe heat treated in a batch-type furnace that is automatically controlled within a 50 °F (28 °C) range and is equipped with recording pyrometers so that heating records are available, a lot shall be defined the same as for continuous furnaces.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 672 – 96(2005), that may impact the use of this specification. (Approved May 1, 2006)

(*1*) References to E55 and E60 were removed throughout.

Standard Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures[1]

This standard is issued under the fixed designation A 671; 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 electric-fusion-welded steel pipe with filler metal added, fabricated from pressure vessel quality plate of several analyses and strength levels and suitable for high-pressure service at atmospheric and lower temperatures. Heat treatment may or may not be required to attain the desired properties or to comply with applicable code requirements. Supplementary requirements are provided for use when additional testing or examination is desired.

1.2 The specification nominally covers pipe 16 in. (405 mm) in outside diameter or larger and of ¼ in. (6.4 mm) wall thickness or greater. Pipe having other dimensions may be furnished provided it complies with all other requirements of this specification.

1.3 Several grades and classes of pipe are provided.

1.3.1 Grade designates the type of plate used as listed in 5.1.

1.3.2 Class designates the type of heat treatment performed during manufacture of the pipe, whether the weld is radiographically examined, and whether the pipe has been pressure tested as listed in 1.3.3.

1.3.3 Class designations are as follows (Note 1):

Class	Heat Treatment on Pipe	Radiography, see Section	Pressure Test, see:
10	none	none	none
11	none	9	none
12	none	9	8.3
13	none	none	8.3
20	stress relieved, see 5.3.1	none	none
21	stress relieved, see 5.3.1	9	none
22	stress relieved, see 5.3.1	9	8.3
23	stress relieved, see 5.3.1	none	8.3
30	normalized, see 5.3.2	none	none
31	normalized, see 5.3.2	9	none
32	normalized, see 5.3.2	9	8.3
33	normalized, see 5.3.2	none	8.3
40	normalized and tempered, see 5.3.3	none	none
41	normalized and tempered, see 5.3.3	9	none
42	normalized and tempered, see 5.3.3	9	8.3
43	normalized and tempered, see 5.3.3	none	8.3
50	quenched and tempered, see 5.3.4	none	none
51	quenched and tempered, see 5.3.4	9	none
52	quenched and tempered, see 5.3.4	9	8.3
53	quenched and tempered, see 5.3.4	none	8.3
60	normalized and precipitation heat treated	none	none
61	normalized and precipitation heat treated	9	none
62	normalized and precipitation heat treated	9	8.3
63	normalized and precipitation heat treated	none	8.3
70	quenched and precipitation heat treated	none	none
71	quenched and precipitation heat treated	9	none
72	quenched and precipitation heat treated	9	8.3
73	quenched and precipitation heat treated	none	8.3

NOTE 1—Selection of materials should be made with attention to temperature of service. For such guidance, Specification A 20/A 20M may be consulted.

1.4 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 20/A 20M Specification for General Requirements for Steel Plates for Pressure Vessels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 435/A 435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 577/A 577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A 578/A 578M Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications

E 110 Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved May 1, 2006. Published May 2006. Originally approved in 1972. Last previous edition approved in 2004 as A 671 – 04.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-671 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.

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

E 165 Test Method for Liquid Penetrant Examination
E 709 Guide for Magnetic Particle Examination

2.2 *Plate Steels:*

A 203/A 203M Specification for Pressure Vessel Plates, Alloy Steel, Nickel
A 285/A 285M Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
A 299/A 299M Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Silicon
A 353/A 353M Specification for Pressure Vessel Plates, Alloy Steel, 9 Percent Nickel, Double-Normalized and Tempered
A 515/A 515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
A 516/A 516M Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
A 517/A 517M Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered
A 537/A 537M Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel
A 553/A 553M Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 8 and 9 % Nickel
A 736/A 736M Specification for Pressure Vessel Plates, Low-Carbon Age-Hardening Nickel-Copper-Chromium-Molybdenum-Columbium and Nickel-Copper-Manganese-Molybdenum-Columbium Alloy Steel

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

Section II, Material Specifications
Section III, Nuclear Vessels
Section VIII, Unfired Pressure Vessels
Section IX, Welding Qualifications

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *lot*—a lot shall consist of 200 ft (61 m) or fraction thereof of pipe from the same heat of steel.

3.1.2 The description of a lot may be further restricted by the use of Supplementary Requirement S14.

4. Ordering Information

4.1 The inquiry and order for material under this specification should include the following information:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (steel pipe, electric-fusionwelded),

4.1.3 Specification number,

4.1.4 Grade and class designations (see 1.3),

4.1.5 Size (inside or outside diameter, nominal or minimum wall thickness),

4.1.6 Length (specific or random),

4.1.7 End finish (11.4),

4.1.8 Purchase options, if any (see 5.2.3 and 11.3 of this specification. See also Specification A 530/A 530M),

4.1.9 Supplementary requirements, if any.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

5. Materials and Manufacture

5.1 *Materials*—The steel plate material shall conform to the requirement of the applicable plate specification for the pipe grade ordered as listed in Table 1.

5.2 *Welding*:

5.2.1 The joints shall be double-welded, full-penetration welds made in accordance with procedures and by welders or welding operators qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

5.2.2 The welds shall be made either manually or automatically by an electric process involving the deposition of filler metal.

5.2.3 As welded, the welded joint shall have positive reinforcement at the center of each side of the weld, but no more than ⅛ in. (3.2 mm). This reinforcement may be removed at the manufacturer's option or by agreement between the manufacturer and purchaser. The contour of the reinforcement shall be smooth and the deposited metal shall be fused smoothly and uniformly into the plate surface.

5.2.4 When radiographic examination in accordance with 9.1 is to be used, the weld reinforcements shall be governed by the more restrictive provision UW–51 of Section VIII of the ASME Boiler and Pressure Vessel Code instead of 5.2.3 of this specification.

5.3 *Heat Treatment*—All classes other than 10, 11, 12, and 13 shall be heat treated in furnace controlled to ± 25 °F (± 14 °C) and equipped with a recording pyrometer so that heating

TABLE 1 Plate Specifications

Pipe Grade	Type of Steel	ASTM Specification	
		No.	Grade
CA 55	plain carbon	A 285/A 285M	C
CB 60	plain carbon, killed	A 515/A 515M	60
CB 65	plain carbon, killed	A 515/A 515M	65
CB 70	plain carbon, killed	A 515/A 515M	70
CC 60	plain carbon, killed, fine grain	A 516/A 516M	60
CC 65	plain carbon, killed, fine grain	A 516/A 516M	65
CC 70	plain carbon, killed, fine grain	A 516/A 516M	70
CD 70	manganese-silicon, normalized	A 537/A 537M	1
CD 80	manganese-silicon, quenched and tempered	A 537/A 537M	2
CF 65	nickel steel	A 203/A 203M	A
CF 70	nickel steel	A 203/A 203M	B
CF 66	nickel steel	A 203/A 203M	D
CF 71	nickel steel	A 203/A 203M	E
CG 100	9 % nickel	A 353/A 353M	
CH 100	9 % nickel	A 553/A 553M	1
CJ 101	alloy steel, quenched and tempered	A 517/A 517M	A
CJ 102	alloy steel, quenched and tempered	A 517/A 517M	B
CJ 103	alloy steel, quenched and tempered	A 517/A 517M	C
CJ 104	alloy steel, quenched and tempered	A 517/A 517M	D
CJ 105	alloy steel, quenched and tempered	A 517/A 517M	E
CJ 106	alloy steel, quenched and tempered	A 517/A 517M	F
CJ 107	alloy steel, quenched and tempered	A 517/A 517M	G
CJ 108	alloy steel, quenched and tempered	A 517/A 517M	H
CJ 109	alloy steel, quenched and tempered	A 517/A 517M	J
CJ 110	alloy steel, quenched and tempered	A 517/A 517M	K
CJ 111	alloy steel, quenched and tempered	A 517/A 517M	L
CJ 112	alloy steel, quenched and tempered	A 517/A 517M	M
CJ 113	alloy steel, quenched and tempered	A 517/A 517M	P
CK 75	carbon-manganese-silicon	A 299/A 299M	
CP65	alloy steel, age hardening, normalized and precipitation heat treated	A 736/A 736M	2
CP75	alloy steel, age hardening, quenched and precipitation heat treated	A 736/A 736M	3

records are available. Heat treating after forming and welding shall be to one of the following:

5.3.1 Classes 20, 21, 22, and 23 pipe shall be uniformly heated within the post-weld heat-treatment temperature range indicated in Table 2 for a minimum of 1 h/in. of thickness or for 1 h, whichever is greater.

5.3.2 Classes 30, 31, 32, and 33, pipe shall be uniformly heated to a temperature in the austenitizing range and not exceeding the maximum normalizing temperature indicated in Table 2 and subsequently cooled in air at room temperature.

5.3.3 Classes 40, 41, 42, and 43 pipe shall be normalized in accordance with 5.3.2. After normalizing, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at temperature for a minimum of ½ h/in. of thickness or for ½ h, whichever is greater, and air cooled.

5.3.4 Classes 50, 51, 52, and 53 pipe shall be uniformly heated to a temperature in the austenitizing range, and not exceeding the maximum quenching temperature indicated in Table 2 and subsequently quenched in water or oil. After quenching, the pipe shall be reheated to the tempering temperature indicated in Table 2 as a minimum and held at that temperature for a minimum of ½ h/in. of thickness or for ½ h, whichever is greater, and air cooled.

5.3.5 Classes 60, 61, 62, and 63 pipe shall be normalized in accordance with 5.3.2. After normalizing, the pipe shall be precipitation heat treated in the range shown in Table 2 for a time to be determined by the manufacturer.

5.3.6 Classes 70, 71, 72, and 73 pipe shall be uniformly heated to a temperature in the austenitizing range, not exceeding the maximum quenching temperature indicated in Table 2, and subsequently quenched in water or oil. After quenching the pipe shall be reheated into the precipitation heat treating range indicated in Table 2 for a time to be determined by the manufacturer.

6. *General Requirements for Delivery* General Requirements for Delivery

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

7. Chemical Composition

7.1 *Product Analysis of Plate*—The pipe manufacturer shall make an analysis of each mill heat of plate material. The product analysis so determined shall meet the requirements of the plate specification to which the material was ordered.

7.2 *Product Analyses of Weld*—The pipe manufacturer shall make an analysis of finished deposited weld material from each 200 ft (61 m) or fraction thereof. Analyses shall conform to the welding procedure for deposited weld metal.

TABLE 2 Heat Treatment Parameters

Pipe Grade[A]	ASTM Specification and Grade	Post-Weld Heat-Treatment Temperature Range °F (°C)	Normalizing Temperature, max, °F (°C)	Quenching Temperature, max, °F (°C)	Tempering Temperature, min, °F (°C)	Precipitation Heat Treatment Temperature Range °F (°C)
CA 55	A 285/A 285M (C)	1100–1250 (590–680)	1700 (925)	...	...	...
CB 60	A 515/A 515M (60)	1100–1250 (590–680)	1750 (950)	...	...	...
CB 65	A 515/A 515M (65)	1100–1250 (590–680)	1750 (950)	...	...	...
CB 70	A 515/A 515M	1100–1250 (590–680)	1750 (950)	...	...	...
CC 60	A 516/A 516M (60)	1100–1250 (590–680)[B]	1700 (925)	1650 (900)	1200 (650)[C]	...
CC 65	A 516/A 516M (65)	1100–1250 (590–680)[B]	1700 (925)	1650 (900)	1200 (650)	...
CC 70	A 516/A 516M (70)	1100–1250 (590–680)[B]	1700 (925)	1650 (900)	1200 (650)	...
CD 70	A 537/A 537M (1)	1100–1250 (590–680)	1700 (925)	...	...	...
CD 80	A 537/A 537M (2)	1100–1250 (590–680)[B]	...	1650 (900)	1100 (590)	...
CF 65	A 203/A 203M (A)	1100–1175 (590–635)	1750 (950)	...	...	...
CF 70	A 203/A 203M (B)	1100–1175 (590–635)	1750 (950)	...	...	...
CF 66	A 203/A 203M (D)	1100–1175 (590–635)	1750 (950)	...	...	...
CF 71	A 203/A 203M (E)	1100–1175 (590–635)	1750 (950)	...	...	...
CG 100	A 353/A 353M	1025–1085 (550–580)	1650 (900)	...	1050 (560)	...
CH 100	A 553/A 553M	1025–1085 (550–580)	1650 (900)	...	1050 (560)	...
CJ 101	A 517/A 517M (A)	1000–1100 (540–590)	...	1725 (940)[D]	1150 (620)	...
CJ 102	A 517/A 517M (B)	1000–1100 (540–590)	...	1725 (940)[D]	1150 (620)	...
CJ 103	A 517/A 517M (C)	1000–1100 (540–590)	...	1725 (940)[D]	1150 (620)	...
CJ 104	A 517/A 517M (D)	1000–1100 (540–590)	...	1725 (940)[D]	1150 (620)	...
CJ 105	A 517/A 517M (E)	1000–1100 (540–590)	...	1725 (940)[D]	1150 (620)	...
CJ 106	A 517/A 517M (F)	1000–1100 (540–590)	...	1725 (940)[D]	1150 (620)	...
CJ 107	A 517/A 517M (G)	1000–1100 (540–590)	...	1725 (940)[D]	1150 (620)	...
CJ 108	A 517/A 517M (H)	1000–1100 (540–590)	...	1725 (940)[D]	1150 (620)	...
CJ 109	A 517/A 517M (J)	1000–1100 (540–590)	...	1725 (940)[D]	1150 (620)	...
CJ 110	A 517/A 517M (K)	1000–1100 (540–590)	...	1725 (940)[D]	1150 (620)	...
CJ 111	A 517/A 517M (L)	1000–1100 (540–590)	...	1725 (940)[D]	1150 (620)	...
CJ 112	A 517/A 517M (M)	1000–1100 (540–590)	...	1725 (940)[D]	1150 (620)	...
CJ 113	A 517/A 517M (P)	1000–1100 (540–590)	...	1725 (940)[D]	1150 (620)	...
CK 75	A 299/A 299M	1100–1250 (590–680)	1700 (925)	...	...	...
CP65	A 736/A 736M (2)	1000–1175 (540–635)	1725 (940)	...	...	1000–1200 (540–650)
CP75	A 736/A 736M (3)	1000–1175 (540–635)	...	1725 (940)	...	1000–1225 (540–665)

[A] Numbers indicate minimum tensile strength in ksi.
[B] In no case shall the post-weld heat-treatment temperature exceed the mill tempering temperature.
[C] Tempering range 1100 to 1300 (590 to 705), if accelerated cooling utilized per Specification A 516/A 516M.
[D] Per ASME Section VIII Specification A 517/A 517M specified 1650 (900) minimum quenching temperature.

7.3 Analysis may be taken from the mechanical test specimens. The results of the analyses shall be reported to the purchaser.

8. Mechanical Requirements

8.1 *Tension Test*:

8.1.1 *Requirements*——Transverse tensile properties of the welded joint shall meet the minimum requirements for ultimate tensile strength of the specified plate material. In addition for Grades CD and CJ, when these are of Class 3x, 4x, or 5x, and Grade CP of Class 6x and 7x, the transverse tensile properties of the base plate shall be determined on specimens cut from the heat-treated pipe. These properties shall meet the mechanical test requirements of the plate specification.

8.1.2 *Number of Tests*—One test specimen of weld metal and one specimen of base metal, if required by 8.1.1, shall be made and tested to represent each lot of finished pipe.

8.1.3 *Test Specimen Location and Orientation*—The test specimens shall be taken transverse to the weld at the end of the finished pipe and may be flattened cold before final machining to size.

8.1.4 *Test Method*—The test specimen shall be made in accordance with QW-150 in Section IX of the ASME Boiler and Pressure Vessel Code. The test specimen shall be tested at room temperature in accordance with Test Methods and Definitions A 370.

8.2 *Transverse Guided Weld Bend Test*:

8.2.1 *Requirements*—The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. (3.2 mm) in any direction are present in the weld metal or between the weld and the base metal after bending. Cracks that originate along the edges of the specimen during testing, and that are less than ¼ in. (6.4 mm) measured in any direction shall not be considered.

8.2.2 *Number of Tests*—One test (two specimens) shall be made to represent each lot of finished pipe.

8.2.3 *Test Specimen Location and Orientation*—Two bend test specimens shall be taken transverse to 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 as the pipe, the test plate being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

8.2.4 *Test Method*—The test requirements of A 370, S9.1.7 shall be met. For wall thicknesses over ⅜ in. (9.5 mm) but less than ¾ in. (19.0 mm) side-bend tests may be made instead of the face and root-bend tests. For wall thicknesses ¾ in. and over both specimens shall be subjected to the side-bend test.

8.3 *Pressure Test*—Classes X2 and X3 pipe shall be tested in accordance with Specification A 530/A 530M, Section 6.

9. Radiographic Examination

9.1 The full length of each weld of Classes X1 and X2 shall be radiographically examined in accordance with and meet the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Paragraph UW–51.

9.2 Radiographic examination may be performed prior to heat treatment.

10. Rework

10.1 *Elimination of Surface Imperfections*—Unacceptable surface imperfections shall be removed by grinding or machining. The remaining thickness of the section shall be no less than the minimum specified in Section 11. The depression after grinding or machining shall be blended uniformly into the surrounding surface.

10.2 *Repair of Base Metal Defects by Welding*:

10.2.1 The manufacturer may repair, by welding, base metal where defects have been removed, provided the depth of the repair cavity as prepared for welding does not exceed ⅓ of the nominal thickness and the requirements of 10.2.2, 10.2.3, 10.2.4, 10.2.5 and 10.2.6 are met. Base metal defects in excess of these may be repaired with prior approval of the customer.

10.2.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the cavity prepared for repair welding.

10.2.3 The welding procedure and welders or welding operators are to be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10.2.4 The full length of the repaired pipe shall be heat treated after repair in accordance with the requirements of the pipe class specified.

10.2.5 Each repair weld of a defect where the cavity, prepared for welding, has a depth exceeding the lesser of ⅜ in. (9.5 mm) or 10 % of the nominal thickness shall be examined by radiography in accordance with the methods and the acceptance standards of Section 9.

10.2.6 The repair surface shall be blended uniformly into the surrounding base metal surface and examined and accepted in accordance with Supplementary Requirements S6 or S8.

10.3 *Repair of Weld Metal Defects by Welding*:

10.3.1 The manufacturer may repair weld metal defects if he meets the requirements of 10.2.3, 10.2.4, 10.3.2, 10.3.3 and 10.4.

10.3.2 The defect shall be removed by suitable mechanical or thermal cutting or gouging methods and the repair cavity examined and accepted in accordance with Supplementary Requirements S7 or S9.

10.3.3 The weld repair shall be blended uniformly into the surrounding metal surfaces and examined and accepted in accordance with 9.1 and with Supplementary Requirements S7 or S9.

10.4 *Retest*—Each length of repaired pipe of a class requiring a pressure test shall be hydrostatically tested following repair.

11. Dimensions, Mass and Permissible Variations

11.1 The wall thickness and weight for welded pipe furnished to this specification shall be governed by the requirements of the specification to which the manufacturer ordered the plate.

11.2 Permissible variations in dimensions at any point in a length of pipe shall not exceed the following:

11.2.1 *Outside Diameter*—Based on circumferential measurement ± 0.5 % of the specified outside diameter.

11.2.2 *Out-of-Roundness*—Difference between major and minor outside diameters, 1 %.

11.2.3 *Alignment*—Using a 10-ft (3-m) straight edge placed so that both ends are in contact with the pipe, ⅛ in. (3.2 mm).

11.2.4 *Thickness*—The minimum wall thickness at any point in the pipe shall not be more than 0.01 in. (0.25 mm) under the specified nominal thickness.

11.3 Circumferential welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

11.4 Lengths with unmachined ends shall be within −0, +½ in. (−0, +13 mm) of that specified. Lengths with machined ends shall be as agreed between the manufacturer and the purchaser.

12. Workmanship, Finish, and Appearance

12.1 The finished pipe shall be free of injurious defects and shall have a workmanlike finish. This requirement is to mean the same as the identical requirement that appears in Specification A 20/A 20M with respect to steel plate surface finish.

13. Product Marking

13.1 In addition to the marking provision of Specification A 530/A 530M, class marking in accordance with 1.3.3 shall follow the grade marking, for example, CC 70–10.

13.2 *Bar Coding*—In addition to the requirements in 13.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Tension and Bend Tests

S1.1 Tension tests in accordance with 8.1 and bend tests in accordance with 8.2 shall be made on specimens representing each length of pipe.

S2. Charpy V-Notch Test

S2.1 *Requirements*—The acceptable test energies for material shown in Specification A 20/A 20M shall conform to the energy values shown in Specification A 20/A 20M.

S2.1.1 Materials not listed in Specification A 20/A 20M shall be in accordance with the purchase order requirements.

S2.2 *Number of Specimens*—Each test shall consist of at least three specimens.

S2.2.1 One base metal test shall be made from one pipe length per heat-treat charge per nominal wall thickness. For pipe from Classes 10, 11, 12, and 13, one base metal test shall be made per heat per size and per wall thickness.

S2.2.2 One weld-metal test shall be made in accordance with UG–84 of Section VIII of the ASME Boiler and Pressure Vessel Code.

S2.2.3 One heat-affected-zone test shall be made in accordance with UG–84 of Section VIII of the ASME Boiler and Pressure Vessel Code.

S2.3 *Test Specimen Location and Orientation:*

S2.3.1 Specimens for base-metal tests in Grades CA, CB, and CC in the as rolled stress relieved or normalized condition (classes of the 10, 20, 30, and 40 series) shall be taken so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the pipe.

S2.3.2 Base-metal specimens of quench and tempered pipe, when the quenching and tempering follows the welding operation, shall be taken in accordance with the provision of N330 of Section III of the ASME Boiler and Pressure Vessel Code.

S2.4 *Test Method*—The specimen shall be Charpy-V Type A in accordance with Test Methods and Definitions A 370. The specimens shall be tested in accordance with Test Methods and Definitions A 370. Unless otherwise indicated by the purchaser, the test temperature shall be as given in Specification A 20/A 20M for those base materials covered by Specification A 20/A 20M. For materials not covered by Specification A 20/A 20M the test temperature shall be 10 °F (−12 °C) unless otherwise stated in the purchase order.

S3. Hardness Test

S3.1 Hardness tests shall be made in accordance with Test Methods and Definitions A 370 or Test Method E 110 across the welded joint of both ends of each length of pipe. In addition, hardness tests shall be made to include the heat-affected zone if so required by the purchaser. The maximum acceptable hardness shall be as agreed upon between the manufacturer and the purchaser.

S3.2 As an alternative to the heat-affected zone hardness, by agreement between the manufacturer and purchaser, maximum heat-affected zone hardness may be specified for the procedure test results.

S4. Product Analysis

S4.1 Product analyses in accordance with 7.1 shall be made on each 500 ft (152 m) of pipe of fraction thereof, or alternatively, on each length of pipe as designated in the order.

S5. Metallography

S5.1 The manufacturer shall furnish one photomicrograph to show the microstructure at 100× magnification of the weld metal or base metal of the pipe in the as-finished condition. The purchaser shall state in the order: the material, base metal or weld, and the number and locations of tests to be made. This test is for information only.

S6. Magnetic Particle Examination of Base Metal

S6.1 All accessible surfaces of the pipe shall be examined in accordance with Guide E 709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. (610 mm) in diameter and greater, and inside surfaces of pipe less than 24 in. in diameter for a distance of 1 pipe diameter from the ends.

S6.2 *Acceptance Standards*—The following relevant indications are unacceptable:

S6.2.1 Any linear indications greater than 1⁄16 in. (1.6 mm) long for materials less than 5⁄8 in (15.9 mm) thick; greater than 1⁄8 in. (3.2 mm) long for materials from 5⁄8 in. thick to under 2 in. (51 mm) thick; and greater than 3⁄16 in. (4.8 mm) long for materials 2 in. thick or greater.

S6.2.2 Rounded indications with dimensions greater than 1⁄8 in. (3.2 mm) for thicknesses less than 5⁄8 in. (15.9 mm), and greater than 3⁄16 in. (4.8 mm) for thicknesses 5⁄8 in. and greater.

S6.2.3 Four or more indications in any line separated by 1⁄16 in. (1.6 mm) or less edge-to-edge.

S6.2.4 Ten or more indications in any 6 in.^{2} (39 cm^2) of surface with the major dimension of this area not to exceed 6 in. (152 mm) when it is taken in the most unfavorable orientation relative to the indications being evaluated.

S7. Magnetic Particle Examination of Weld Metal

S7.1 All accessible welds shall be examined in accordance with Guide E 709. Accessible is defined as: All outside surfaces, all inside surfaces of pipe 24 in. (610 mm) in diameter and greater, and inside surfaces of pipe less than 24 in. in diameter for a distance of one pipe diameter from the ends.

S7.2 *Acceptance Criteria*—The following relevant indications are unacceptable:

S7.2.1 Any cracks and linear indications.

S7.2.2 Rounded indications with dimensions greater than 3⁄16 in. (4.8 mm).

S7.2.3 Four or more indications in any line separated by 1⁄16 in. (1.6 mm) or less edge-to-edge.

S7.2.4 Ten or more indications in any 6 in.^{2}(39 cm^2) of surface with the major dimension of this area not to exceed 6 in. (152 mm) when it is taken in the most unfavorable orientation relative to the indications being evaluated.

S8. Liquid Penetrant Examination of Base Metal

S8.1 All accessible surfaces of the pipe shall be examined in accordance with Test Method E 165. Accessible is as defined in S7.1.

S8.2 The acceptance criteria shall be in accordance with S6.2.

S9. Liquid Penetrant Examination of Weld Metal

S9.1 All accessible surfaces of the pipe shall be examined in accordance with Test Method E 165. Accessible is as defined in S7.1.

S9.2 The acceptance criteria shall be in accordance with S7.2.

S10. Straight Beam Ultrasonic Examination of Flat Plate—UT 1

S10.1 The plate shall be examined and accepted in accordance with Specification A 435/A 435M except that 100 % of one surface shall be scanned by moving the search unit in parallel paths with not less than 10 % overlap.

S11. Straight Beam Ultrasonic Examination of Flat Plate—UT 2

S11.1 The plate shall be examined in accordance with Specification A 578/A 578M except that 100 % of one surface shall be scanned and the acceptance criteria shall be as follows:

S11.1.1 Any area, where one or more discontinuities produce a continuous total loss of back reflection accompanied by continuous indications on the same plane that cannot be encompassed within a circle whose diameter is 3 in. (76.2 mm) or one half of the plate thickness, whichever is greater, is unacceptable.

S11.1.2 In addition, two or more discontinuities on the same plane and having the same characteristics but smaller than described above shall be unacceptable unless separated by a minimum distance equal to the largest diameter of the larger discontinuity or unless they may be collectively encompassed by the circle described above.

S12. Angle Beam Ultrasonic Examination (Plate Less than 2 in. (50.8 mm) Thick)—UT 3

S12.1 The plate shall be examined in accordance with Specification A 577/A 577M except that the calibration notch shall be vee shaped and the acceptance criteria shall be as follows: Any area showing one or more reflections producing indications whose amplitude exceeds that of the calibration notch is unacceptable.

S13. Repair Welding

S13.1 Repair of base metal defects by welding shall be done only with customer approval.

S14. Description of Term

S14.1 *lot*—all pipe of the same mill heat of plate material and wall thickness (within ±1⁄4 in. (6.4 mm)) heat treated in one furnace charge. For pipe that is not heat treated or that is heat treated in a continuous furnace, a lot shall consist of each 200 ft (61 m) or fraction thereof of all pipe of the same mill heat of plate material and wall thickness (within ±1⁄4 in. (6.4 mm)), subjected to the same heat treatment. For pipe heat treated in a batch-type furnace that is automatically controlled within a 50 °F (28 °C) range and is equipped with recording pyrometers so that heating records are available, a lot shall be defined the same as for continuous furnaces.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 671 – 04, that may impact the use of this specification. (Approved May 1, 2006)

(*1*) Removed references to CE55 and CE60 throughout.

Designation: A 632 – 04

Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service[1]

This standard is issued under the fixed designation A 632; 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 covers grades of stainless steel tubing in sizes under ½ down to 0.050 in. (12.7 to 1.27 mm) in outside diameter and wall thicknesses less than 0.065 in. down to 0.005 in. (1.65 to 0.13 mm) for general corrosion-resisting and low- or high-temperature service, as designated in Table 1.

NOTE 1—The grades of austenitic stainless steel tubing furnished in accordance with this specification have been found suitable for low-temperature service down to −325°F (−200°C) in which Charpy notched-bar impact values of 15 ft·lbf (20 J), minimum, are required and these grades need not be impact tested.

1.2 Optional supplementary requirements are provided and, when desired, shall be so stated in the order.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 165 Test Method for Liquid Penetrant Examination

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *SAE Standard:*

SAE J 1086 Practice for Numbering Metals and Alloys (UNS)[3]

3. Ordering Information

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

3.1.1 Quantity (feet or number of lengths),

3.1.2 Name of product (seamless or welded tubes),

3.1.3 Grade (see Table 1),

3.1.4 Size (only two of the following: outside diameter, inside diameter, and average wall),

3.1.5 Length (specific or random),

3.1.6 Optional requirements (check analysis, see Section 7; hydrostatic, air underwater pressure test, or nondestructive electric test, see Section 13),

3.1.7 Test report required,

3.1.8 Specification designation, and

3.1.9 Special requirements or any supplementary requirements selected, or both.

4. General Requirements

4.1 Tubing 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. Manufacture

5.1 *Manufacture*—The tubes shall be cold finished and shall be made by the seamless or welded process.

5.2 *Heat Treatment*—All material shall be furnished in the heat-treated condition. The heat-treatment procedure shall consist of heating the material to a minimum temperature of 1800°F (980°C) and quenching in water or rapidly cooling by other means.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition as specified in Table 1.

[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.

Current edition approved March 1, 2004. Published March 2004. Originally approved in 1969. Last previous edition approved in 2002 as A 632 – 02a.

[2] 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.

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

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

TABLE 1 Chemical Requirements

Element	Composition, %								
	Grade	TP 304	TP 304L	TP 310	TP 316	TP 316L	TP 317	TP 321	TP 347	TP 348
	UNS Designation^{A}	S30400	S30403	S31000	S31600	S31603	S31700	S32100	S34700	S34800
Carbon, max		0.08	0.030	0.15	0.08	0.030	0.08	0.08	0.08	0.08
Manganese max		2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Phosphorus, max		0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
Sulfur, max		0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
Silicon, max		0.75	0.75	0.75	0.75	0.75^{B}	0.75	0.75	0.75	0.75
Nickel		8.0–11.0	8.0–13.0	19.0–22.0	11.0–14.0^{C}	10.0–15.0	11.0–14.0	9.0–13.0	9.0–13.0	9.0–13.0
Chromium		18.0–20.0	18.0–20.0	24.0–26.0	16.0–18.0	16.0–18.0	18.0–20.0	17.0–20.0	17.0–20.0	17.0–20.0
Molybdenum		...	...	...	2.00–3.00	2.00–3.00	3.00–4.00	...	...	...
Titanium		...	...	...	...	...	...	^{D}	...	...
Columbium + tantalum		...	...	...	...	...	...	...	^{E}	^{E}
Tantalum, max		...	...	...	...	...	...	...	...	0.10

^{A} New designation established in accordance with Practice E 527 and SAE J 1086, Practice for Numbering Metals and Alloys (UNS).
^{B} For seamless TP316L tubes, the silicon maximum shall be 1.00 %.
^{C} For welded TP 316 tubes, the nickel range shall be 10.0–14.0 %.
^{D} Grade TP 321 shall have a titanium content of not less than five times the carbon content and not more than 0.60 %.
^{E} Grades TP 347 and TP 348 shall have a columbium plus tantalum content of not less than ten times the carbon content and not more than 1.0 %.

7. Product Analysis

7.1 When specified on the purchase order, an analysis of either one billet or one length of flat-rolled stock or one tube shall be made from each heat. The chemical composition thus determined shall conform to the specified requirements.

7.2 If the analysis made in accordance with 7.1 does not conform to the specified requirements, an analysis of each billet or length of flat-rolled stock or tube from the same heat may be made and all billets, stock, or tubes thus conforming to the requirements shall be accepted so far as chemical composition is concerned.

8. Mechanical Properties

8.1 *Tensile Requirements*—The material shall conform to the requirements as to tensile properties specified in Table 2. These mechanical properties apply to tubing ⅛ in. (3.2 mm) and larger in outside diameter by 0.015 in. (0.38 mm) in wall thickness and heavier. Smaller sizes are available meeting the minimum tensile strength specified in Table 2; however, yield strength is not generally determined on such sizes, and the minimum elongation shall be 25 %.

9. Permissible Variations in Dimensions

9.1 Variations in diameter and wall thickness from those specified shall not exceed the amounts specified in Table 3.

10. Surface Condition

10.1 The tubes shall be pickled free of scale. When bright annealing is used, pickling is not required.

TABLE 2 Tensile Requirements

Tensile strength, min, ksi (MPa)	75^{A} (515)^{A}
Yield strength, min, ksi (MPa)	30^{A,B} (205)^{A,B}
Elongation in 2 in. or 50 mm, min, %	35^{B}

^{A} Grades TP 304L and TP 316L shall have a minimum tensile strength of 70 ksi (485 MPa) and a minimum yield strength of 25 ksi (170 MPa).
^{B} Yield strength is not generally determined on tubing sizes smaller than ⅛ in. (3.2 mm) in outside diameter or thinner than 0.015 in. (0.38 mm) wall, so yield strength is not required on such sizes. Also, the minimum elongation required on these smaller or thinner sizes is 25 %.

TABLE 3 Permissible Variations in Dimensions

Outside Diameter Range	Outside Diameter, in. (mm)	Inside Diameter, in. (mm)	Wall, plus and minus, %
Up to, but not including 3⁄32 (0.094) in. (2.38 mm)	+0.002 (0.05) −0.000	+0.000 −0.002 (0.05)	10
3⁄32 (0.094) in. (2.38 mm) but not including 3⁄16 (0.188) in. (4.76 mm)	+0.003 (0.08) −0.000	+0.000 −0.003 (0.08)	10
3⁄16 to, but not including, ½ (0.500) in. (12.70 mm)	+0.004 (0.10) −0.000	+0.000 −0.004 (0.10)	10

11. Number of Tests

11.1 For each lot of 100 finished tubes or fraction thereof, two tubes shall be selected at random for the flaring test (see Note 2).

11.2 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 (see Note 3).

NOTE 2—For flaring requirements, the term *lot* applies to all tubes of the same nominal size and wall thickness that are produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace; when final heat treatment is in a batch-type furnace, the lot shall include only those tubes that are heat treated in the same furnace charge.

NOTE 3—For tensile requirements, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that 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 that 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.

11.3 When more than one heat is involved, the test requirements prescribed in 12.1 shall apply to each heat.

11.4 Each tube shall be subjected to a pressure test or the nondestructive test described in Section 13.

12. Flaring Test

12.1 *Flaring Test*—A section of tube approximately 4 in. (101.6 mm) in length shall stand being flared with a tool having a 60° included angle until the tube at the mouth of the flare has been expanded to the following percentages without cracking or showing flaws:

Ratio of Inside Diameter to Outside Diameter	Minimum Expansion of Inside Diameter, %
0.9	21
0.8	22
0.7	25
0.6	30
0.5	39
0.4	51
0.3	68

NOTE 4—These flare tests shall not be required on sizes under 0.093 in. (2.38 mm) in inside diameter.

13. Hydrostatic, Air Underwater Pressure Test, or Nondestructive Electric Test

13.1 Each tube shall be subjected to the hydrostatic test, air underwater pressure test, or nondestructive electric test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

13.2 *Hydrostatic Test*:

Each tube shall be subjected to a hydrostatic test at a test pressure not exceeding 1000 psi (6.89 MPa).

13.3 *Air Underwater Pressure Test*:

Each tube shall be subjected to an air underwater pressure test, at a test pressure as given by the following equation or 500 psi (3.4 MPa), whichever is less:

$$P = 2St / D \quad (1)$$

where:

P = air pressure, psi or MPa
S = allowable fiber stress of 16,000 psi (110.3 MPa),
t = specified wall thickness, in. or mm, and
D = specified outside diameter, in. or mm.

13.4 *Nondestructive Electric Test*:

13.5 Each tube shall be subjected to a nondestructive electric test that is capable of detecting imperfections with a depth exceeding 10 % of the wall thickness or 0.002 in. (0.05 mm), whichever is greater. Testing will not be required on sizes under 0.125 in. (3.18 mm) in outside diameter. However, at the option of the purchaser, tubing to be drawn to a diameter under 0.125 in. may be tested while in the range from 0.156 in. (3.97 mm) to 0.125 in. outside diameter, and any defects that are found shall be culled out before any further reductions are made.

14. Keywords

14.1 austenitic stainless steel; seamless tube; small diameter; stainless steel tube; steel tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

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

S1. Dye Penetrant Inspection

S1.1 Each tube shall be submitted to a visible dye or fluorescent dye penetrant examination. The procedure for this specification shall conform to Test Method E 165. The type penetrant and the acceptance level shall be agreed upon between the purchaser and manufacturer.

S2. Embrittlement Test

S2.1 Tubing shall be capable of meeting the intergranular corrosion test specified in Practice E of Practices A 262 in the as-shipped condition. Stabilized and low-carbon grades shall be capable of meeting the requirements of this test in the sensitized condition (1 h at 1240°F [675°C]).

S3. Cleanliness

S3.1 When specified, tubing shall be supplied *thermocouple clean* on the inside surface. *Thermocouple clean* is defined as being free of all drawing compounds, carbon, dirt, dust, visible surface oxides, scale, and other contaminants.

S3.1.1 Verify the freedom from inside visible surface oxides and scale by cutting two short lengths of tubing as specimens and longitudinally sectioning both. Pickle one of the specimens in accordance with Specification A 380 and then wash both. Visually, without magnification, compare the pickled and unpickled specimens to confirm that neither exhibits surface oxides or scale on their inside surfaces.

S3.1.2 Verify cleanliness and freedom from contaminants, such as drawing compounds, carbon, dirt, and dust, by passing a solvent-saturated swatch of lint-free yarn or cloth, or a felt plug through the tube. Isopropyl alcohol, methanol, ethanol, denatured alcohol, or acetone followed by alcohol are acceptable solvents. Because acetone leaves a residual film, cleaning with acetone alone is not acceptable. While a heavy discoloration of the swatch or plug is unacceptable, a light discoloration is acceptable unless particles of grit or metallic flakes are visually detectable without the use of magnification.

S3.2 After verifying that the inside surface is thermocouple clean, the tubing shall be capped or otherwise protected to ensure cleanliness upon arrival at its destination. The producer and purchaser shall agree on the method of protection.

S4. Unstraightened Tubes

S4.1 When the purchaser specifies tubes unstraightened after final heat treatment (such as coils), the minimum yield strength of Table 2 shall be reduced by 5 ksi.

S4.2 On the certification, and wherever the grade designation for unstraightened tubing appears, it shall be identified with the suffix letter *U* (for example, 304-U, 321-U, and so forth.).

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 632 – 02a, that may impact the use of this specification. (Approved March 1, 2004)

(1) Added reference to Specification A 380 in Referenced Documents and Supplementary Requirement S3.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 632 – 02, that may impact the use of this specification. (Approved September 10, 2002)

(1) Reference to Specification A 1016/A 1016M has been added.
(2) References to Test Methods and Definitions A 370, Terminology A 941, and Test Methods A 751 have been deleted from Section 2 and throughout the standard.
(3) Section 12 was renamed from "Manipulation Test" to "Flaring Test."
(4) Section on Terminology was deleted.
(5) Section on General Requirements was added.
(6) Paragraphs 7.1 and 7.2 were revised.
(7) Sections on Retests, Retreatment, Test Specimens and Test Methods, Inspection, Rejection, Certification, and Product Marking were deleted.
(8) Section 13 was revised.

Designation: A 618/A 618M – 04

Standard Specification for Hot-Formed Welded and Seamless High-Strength Low-Alloy Structural Tubing[1]

This standard is issued under the fixed designation A 618/A 618M; 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*

1.1 This specification covers grades of hot-formed welded and seamless high-strength low-alloy square, rectangular, round, or special shape structural tubing for welded, riveted, or bolted construction of bridges and buildings and for general structural purposes. When the steel is used in welded construction, the welding procedure shall be suitable for the steel and the intended service.

1.2 Grade II has atmospheric corrosion resistance equivalent to that of carbon steel with copper (0.20 minimum Cu) Grades Ia and Ib have atmospheric corrosion resistance substantially better than that of Grade II (Note 1). When properly exposed to the atmosphere, Grades Ia and Ib can be used bare (unpainted) for many applications. When enhanced corrosion resistance is desired, Grade III, copper limits may be specified.

NOTE 1—For methods of estimating the atmospheric corrosion resistance of low alloy steels see Guide G 101 or actual data.

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 shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

G 101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels

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, metres, or number of lengths),

3.1.2 Grade (Table 1 and Table 2),

3.1.3 Material (round, square, or rectangular tubing),

3.1.4 Method of manufacture (seamless, buttwelded, or hot-stretch-reduced electric-resistance welded),

3.1.5 Size (outside diameter and nominal wall thickness for round tubing and the outside dimensions and calculated nominal wall thickness for square and rectangular tubing),

3.1.6 Length (specific or random, see 8.2),

3.1.7 End condition (see 9.2),

3.1.8 Burr removal (see 9.2),

3.1.9 Certification (see 12.1),

3.1.10 Specification designation (A 618 or A 618M, including yeardate),

3.1.11 End use, and

3.1.12 Special requirements.

4. Process

4.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

4.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

5. Manufacture

5.1 The tubing shall be made by the seamless, furnace-buttwelded (continuous-welded), or hot-stretch-reduced electric-resistance-welded process.

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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 A01.09 on Carbon Steel Tubular Products.

Current edition approved March 1, 2004. Published March 2004. Originally approved in 1968. Last previous edition approved in 2001 as A 618–01.

[2] 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.

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

TABLE 1 Chemical Requirements

Element	Composition, %							
	Grade Ia		Grade Ib		Grade II		Grade III	
	Heat	Product	Heat	Product	Heat	Product	Heat	Product
Carbon, max	0.15	0.18	0.20	. . .	0.22	0.26	0.23[A]	0.27[A]
Manganese	1.00 max	1.04 max	1.35 max	1.40 max	0.85–1.25	1.30 max	1.35 max[A]	1.40 max[A]
Phosphorus, max	0.15	0.16	0.025	0.035	0.025	0.035	0.025	0.035
Sulfur, max	0.025	0.045	0.025	0.035	0.025	0.035	0.025	0.035
Silicon, max	. . .	. . .	. . .	. . .	0.30	0.33	0.30	0.35
Copper, min	0.20	0.18	0.20[B]	0.18[B]	0.20	0.18	. . .	. . .
Vanadium, min	. . .	. . .	. . .	. . .	0.02	0.01	0.02[C]	0.01

[A] For each reduction of 0.01 % C below the specified carbon maximum, an increase of 0.05 % manganese above the specified maximum will be permitted up to 1.45 % for the heat analysis and up to 1.50 % for the product analysis.
[B] If chromium and silicon contents are each 0.50 % min, then the copper minimums do not apply.
[C] For Grade III, columbium may be used in conformance with the following limits: 0.005 %, min (heat) and 0.004 %, min (product).

TABLE 2 Tensile Requirements

	Grades Ia, Ib, and II				Grade III	
	Walls ¾ in. [19.0 mm] and Under		Walls over ¾ to 1½ in. [19.0 to 38.0 mm], incl			
Tensile strength, min, ksi [MPa][A]	70	[485]	67	[460]	65	[450]
Yield strength, min, ksi [MPa][A]	50	[345]	46	[315]	50	[345]
Elongation in 2 in. or 50 mm, min, %	22		22		20	
Elongation in 8 in. or 200 mm, min, %	19		18		18	

[A] For Grade II, when the material is normalized, the minimum yield strength and minimum tensile strength required shall be reduced by 5 ksi [35 MPa].

6. Chemical Composition

6.1 When subjected to the heat and product analysis, respectively, the steel shall conform to the requirements prescribed in Table 1.

6.1.1 For Grades Ia and Ib, the choice and use of alloying elements, combined with carbon, manganese, and sulfur within the limits prescribed in Table 1 to give the mechanical properties prescribed in Table 2 and to provide the atmospheric corrosion resistance of 1.2, should be made by the manufacturer and included and reported in the heat analysis for information purposes only to identify the type of steel applied. For Grades Ia and Ib material, the atmospheric corrosion-resistance index, calculated on the basis of the chemical composition of the steel as described in Guide G 101, shall be 6.0 or higher.

NOTE 2—The user is cautioned that the Guide G 101 predictive equation for calculation of an atmospheric corrosion–resistance index has been verified only for the composition limits stated in that guide.

6.1.2 When Grade III is required for enhanced corrosion resistance, copper limits may be specified and the minimum content shall be 0.20 % by heat analysis and 0.18 % by product analysis.

6.2 *Heat Analysis*—An analysis of each heat of open-hearth, basic-oxygen, or electric-furnace steel shall be made by the manufacturer. This analysis shall be made from a test ingot taken during the pouring of the heat. The chemical composition thus determined shall conform to the requirements specified in Table 1 for heat analysis.

6.3 *Product Analysis*:

6.3.1 An analysis may be made by the purchaser from finished tubing manufactured in accordance with this specification, or an analysis may be made from flat-rolled stock from which the welded tubing is manufactured. When product analyses are made, two sample lengths from a lot of each 500 lengths, or fraction thereof, shall be selected. The specimens for chemical analysis shall be taken from the sample lengths in accordance with the applicable procedures of Test Methods, Practices, and Terminology A 751. The chemical composition thus determined shall conform to the requirements specified in Table 1 for product analysis.

6.3.2 In the event the chemical composition of one of the sample lengths does not conform to the requirements shown in Table 1 for product analysis, an analysis of two additional lengths selected from the same lot shall be made, each of which shall conform to the requirements shown in Table 1 for product analysis, or the lot is subject to rejection.

7. Mechanical Requirements

7.1 *Tensile Properties*:

7.1.1 The material, as represented by the test specimen, shall conform to the requirements prescribed in Table 2.

7.1.2 Elongation may be determined on a gage length of either 2 in. [50 mm] or 8 in. [200 mm] at the manufacturer's option.

7.1.3 For material under 5⁄16 in. [8.0 mm] in thickness, a deduction from the percentage elongation of 1.25 percentage points in 8 in. [200 mm] specified in Table 2 shall be made for each decrease of 1⁄32 in. [0.8 mm] of the specified thickness under 5⁄16 in. [8.0 mm].

7.2 *Bend Test*—The bend test specimen shall stand being bent cold through 180° without cracking on the outside of the bent portion, to an inside diameter which shall have a relation to the thickness of the specimen as prescribed in Table 3.

7.3 *Number of Tests*—Two tension and two bend tests, as specified in 7.4.2, and 7.4.3, shall be made from tubing representing each heat. However, if tubing from one heat differs in the ordered nominal wall thickness, one tension test and one bend test shall be made from both the heaviest and lightest wall thicknesses processed.

TABLE 3 Bend Test Requirements

Thickness of Material, in. [mm]	Ratio of Bend Diameter to Specimen Thickness
¾ [19.0] and under	1
Over ¾ to 1 [19.0 to 25.0], incl	1½
Over 1 [25.0]	2

7.4 *Test Specimens*:

7.4.1 The test specimens required by this specification shall conform to those described in the latest issue of Test Methods and Definitions A 370.

7.4.2 The tension test specimen shall be taken longitudinally from a section of the finished tubing, at a location at least 90° from the weld in the case of welded tubing, and shall not be flattened between gage marks. If desired, the tension test may be made on the full section of the tubing; otherwise, a longitudinal strip test specimen shall be used as prescribed in Test Methods and Definitions A 370, Annex A2. The specimens shall have all burrs removed and shall not contain surface imperfections that would interfere with the proper determination of the tensile properties of the metal.

7.4.3 The bend test specimen shall be taken longitudinally from the tubing, and shall represent the full wall thickness of material. The sides of the bend test specimen may have the corners rounded to a maximum radius of 1⁄16 in. [1.6 mm].

7.5 *Test Methods*:

7.5.1 The yield strength shall be determined in accordance with one of the alternatives described in Test Methods and Definitions A 370.

7.5.2 The bend test shall be made on square or rectangular tubing manufactured in accordance with this specification.

7.6 *Retests:*

7.6.1 If the results of the mechanical tests representing any heat do not conform to a requirement, as specified in 7.1 and 7.2, retests may be made on additional tubing of double the original number from the same heat, each of which shall conform to the requirement specified, or the tubing represented by the test is subject to rejection.

7.6.2 In case of failure on retest to meet the requirements of 7.1 and 7.2, the manufacturer may elect to retreat, rework, or otherwise eliminate the condition responsible for failure to meet the specified requirements. Thereafter, the material remaining from the respective heat originally represented may be tested, and shall comply with all requirements of this specification.

8. Dimensions and Permissible Variations

8.1 The dimensions of square, rectangular, round, and special shape structural tubing to be ordered under this specification shall be subject to prior negotiation with the manufacturer. The dimensions agreed upon shall be indicated in the purchase order.

8.2 *Permissible Variations*:

8.2.1 *Outside Dimensions*:

8.2.1.1 For round tubing 2 in. [50 mm] and over in nominal diameter, the outside diameter shall not vary more than ±1 % from the specified outside diameter. For sizes 1½ in. [38 mm] and under, the outside diameter shall not vary more than 1⁄64 in. [0.4 mm] over and more than 1⁄32 in. [0.8 mm] under the specified outside diameter.

8.2.1.2 The specified dimensions, measured across the flats at positions at least 2 in. [50 mm] from either end of square and rectangular tubing and including an allowance for convexity and concavity, shall not exceed the plus and minus tolerance shown in Table 4.

TABLE 4 Outside Dimension Tolerances for Square, Rectangular, and Special Shape Structural Tubing

Largest Outside Dimension Across Flats, in. [mm]	Tolerance ± in. [mm]
2½ [64] and under	0.020 [0.5]
Over 2½ to 3½ [64 to 89], incl	0.025 [0.6]
Over 3½ to 5½ [89 to 140], incl	0.030 [0.8]
Over 5½ [140]	1 %

8.2.2 *Mass*—The mass of structural tubing shall not be less than the specified value by more than 3.5 %. The mass tolerance shall be determined from individual lengths or for round tubing sizes 4½ in. [114 mm] in outside diameter and under and square and rectangular tubing having a periphery of 14 in. [356 mm] and under shall be determined from masses of the customary lifts produced by the mill. On round tubing sizes over 4½ in. [114 mm] in outside diameter and square and rectangular tubing having a periphery in excess of 14 in. [356 mm] the mass tolerance is applicable to the individual length.

8.2.3 *Length*—Structural tubing is commonly produced in random mill lengths of 16 to 22 ft [4.9 to 6.7 m] or 32 to 44 ft [9.8 to 13.4 m], in multiple lengths, and in definite cut lengths (Section 3). When cut lengths are specified for structural tubing, the length tolerances shall be in accordance with Table 5.

8.2.4 *Straightness*—The permissible variation for straightness of structural tubing shall be 1⁄8 in. times the number of feet of total length divided by 5 [2 mm times length in metres).

8.2.5 *Squareness of Sides*—For square or rectangular structural tubing, adjacent sides may deviate from 90° by a tolerance of ±2°, maximum.

8.2.6 *Radius of Corners*—For square or rectangular structural tubing, the radius of any outside corner of the section shall not exceed three times the specified wall thickness.

8.2.7 *Twist*:

8.2.7.1 The tolerance for twist, or variation with respect to axial alignment of the section for square, rectangular, or special shape structural tubing, shall be as prescribed in Table 6.

8.2.7.2 Twist is measured by holding down one end of a square or rectangular tube on a flat surface plate with the bottom side of the tube parallel to the surface plate, and noting the height that either corner at the opposite end of the bottom side of the tube extends above the surface plate. The difference in the height of the corners shall not exceed the values in Table 6.

9. Workmanship, Finish, and Appearance

9.1 The structural tubing shall be free of defects and shall have a commercially smooth finish.

9.1.1 Surface imperfections shall be classed as defects when their depth exceeds 15 % of the specified wall thickness and when the imperfections materially affected the appearance of

TABLE 5 Cut Length Tolerances for Structural Tubing

	22 ft [6.7 m] and Under		Over 22 to 44 ft [6.7 to 13.4 m], incl	
	Over	Under	Over	Under
Length tolerance for specified cut lengths, in. [mm]	½ [13]	¼ [6]	¾ [19]	¼ [6]

TABLE 6 Twist Tolerances for Square, Rectangular, or Special Shape Structural Tubing

Specified Dimension of Longest Outside Side, in. [mm]	Maximum Twist per 3 ft of Length, in.	Maximum Twist per Metre of Length, mm
1½ [38] and under	0.050	1.4
Over 1½ to 2½ [38 to 64], incl	0.062	1.7
Over 2½ to 4 [64 to 102], incl	0.075	2.1
Over 4 to 6 [102 to 152], incl	0.087	2.4
Over 6 to 8 [152 to 203], incl	0.100	2.8
Over 8 [203]	0.112	3.1

the structural member, or when their length (measured in a transverse direction) and depth would materially reduce the total cross-sectional area at any location.

9.1.2 Defects having a depth not in excess of 33⅓ % of the wall thickness may be repaired by welding, subject to the following conditions:

9.1.2.1 The defect shall be completely removed by chipping or grinding to sound metal.

9.1.2.2 The repair weld shall be made using suitable coated electrodes.

9.1.2.3 The projecting weld metal shall be removed to produce a workmanlike finish.

9.2 The ends of structural tubing, unless otherwise specified, shall be finished square cut, and the burr held to a minimum. The burr can be removed on the outside diameter, inside diameter, or both, as a supplementary requirement. When the burrs are to be removed, it shall be specified in the purchase order.

10. Inspection

10.1 All tubing shall be subject to an inspection at the place of manufacture to assure conformance with the requirements of this specification.

11. Rejection

11.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

11.2 Tubing found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such tubing shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

12. Certification

12.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification (including year of issue) together with a report of the chemical and tensile tests shall be furnished.

13. Packaging, Package Marking, and Loading

13.1 Except as noted in 13.2, each length of structural tubing shall be legibly marked by rolling, die stamping, ink printing, or paint stenciling to show the following information: manufacturer's name, brand, or trademark; size and wall thickness; steel grade; and the specification number (year of issue not required).

13.2 For structural tubing 1½ in. [38 mm] and under in nominal size or the greatest cross sectional dimension less than 2 in. [50 mm], the information listed in 10.1 may be marked on a tag securely attached to each bundle.

13.3 When specified in the order, contract, etc., packaging, marking, and loading shall be in accordance with the procedures of Practices A 700.

13.4 *Bar Coding*—In addition to the requirements in 13.1, 13.2, and 13.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

14. Keywords

14.1 high-strength low-alloy steel; seamless steel tube; steel tube; structural steel tubing; welded steel tubing

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard that have been incorporated since the last issue (A 618–01) that may impact the use of this standard.

(1) Rationalized SI units have been added throughout the text and tables to create a combined standard.

Designation: A 608/A 608M – 06

Standard Specification for Centrifugally Cast Iron-Chromium-Nickel High-Alloy Tubing for Pressure Application at High Temperatures[1]

This standard is issued under the fixed designation A 608/A 608M; 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*

1.1 This specification covers iron-chromium-nickel, high-alloy tubes made by the centrifugal casting process intended for use under pressure at high temperatures.

1.2 The grades of high alloys detailed in Table 1 are intended for applications requiring strength and resistance to corrosion and scaling at high temperatures.

1.3 Optional Supplementary Requirements S1 to S11 are provided; these call for additional tests to be made if desired.

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 each other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 342/A 342M Test Methods for Permeability of Feebly Magnetic Materials

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

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

E 8 Test Methods for Tension Testing of Metallic Materials

E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials

E 94 Guide for Radiographic Examination

E 139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

E 142 Method for Controlling Quality of Radiographic Testing[3]

E 151 Recommended Practice for Tension Tests of Metallic Materials at Elevated Temperatures With Rapid Heating and Conventional or Rapid Strain Rates[3]

E 165 Test Method for Liquid Penetrant Examination

E 340 Test Method for Macroetching Metals and Alloys

3. Ordering Information

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

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

3.1.2 Name of material (centrifugally cast tubing),

3.1.3 Specification number and grade (Table 1),

3.1.4 Size (outside or inside diameter and minimum wall thickness, see Section 8).

3.1.5 Condition (see Section 9, as cast or as cast with machining on outside or inside surfaces, or machined; see 5.1, 8, and 9),

3.1.6 Length (specific or random), (Permissible Variations in Length Section of Specification A 999/A 999M),

3.1.7 End finish (Ends Section of Specification A 999/A 999M),

3.1.8 Optional requirements (see 8.2.3 regarding the manufacturer's wall thickness allowance for as cast tubing and Supplementary Requirements S1 to S11),

3.1.9 Test report required (see Section 13), and

[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 A01.18 on Castings.

Current edition approved Sept. 1, 2006. Published September 2006. Originally approved in 1970. Last previous edition approved in 2002 as A 608/A 608M – 02.

[2] 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.

[3] Withdrawn.

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

TABLE 1 Chemical Requirements

Grade	Composition, %							
	Carbon	Manganese	Silicon	Chromium	Nickel	Phosphorus	Sulfur	Molybdenum
HC30	0.25–0.35	0.5–1.0	0.50–2.00	26–30	4.0 max	0.04 max	0.04 max	0.50 max
HD50	0.45–0.55	1.50 max	0.50–2.00	26–30	4–7	0.04 max	0.04 max	0.50 max
HE35	0.30–0.40	1.50 max	0.50–2.00	26–30	8–11	0.04 max	0.04 max	0.50 max
HF30	0.25–0.35	1.50 max	0.50–2.00	19–23	9–12	0.04 max	0.04 max	0.50 max
HH30	0.25–0.35	1.50 max	0.50–2.00	24–28	11–14	0.04 max	0.04 max	0.50 max
HH33[A]	0.28–0.38	1.50 max	0.50–2.00	24–26	12–14	0.04 max	0.04 max	0.50 max
HI35	0.30–0.40	1.50 max	0.50–2.00	26–30	14–18	0.04 max	0.04 max	0.50 max
HK30	0.25–0.35	1.50 max	0.50–2.00	23–27	19–22	0.04 max	0.04 max	0.50 max
HK40	0.35–0.45	1.50 max	0.50–2.00	23–27	19–22	0.04 max	0.04 max	0.50 max
HL30	0.25–0.35	1.50 max	0.50–2.00	28–32	18–22	0.04 max	0.04 max	0.50 max
HL40	0.35–0.45	1.50 max	0.50–2.00	28–32	18–22	0.04 max	0.04 max	0.50 max
HN40	0.35–0.45	1.50 max	0.50–2.00	19–23	23–27	0.04 max	0.04 max	0.50 max
HT50	0.40–0.60	1.50 max	0.50–2.00	15–19	33–37	0.04 max	0.04 max	0.50 max
HU50	0.40–0.60	1.50 max	0.50–2.00	17–21	37–41	0.04 max	0.04 max	0.50 max
HW50	0.40–0.60	1.50 max	0.50–2.00	10–14	58–62	0.04 max	0.04 max	0.50 max
HX50	0.40–0.60	1.50 max	0.50–2.00	15–19	64–68	0.04 max	0.04 max	0.50 max

[A] Manufacturing control should ensure that this composition contain a minimal amount of ferrite. See Supplementary Requirement S5.

3.1.10 Special requirements to be added to the specification.

4. General Requirements

4.1 Material furnished under 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 The tubing may be supplied in the as cast condition or as cast with machining on the outside or inside surfaces, or machined, as agreed upon between the manufacturer and the purchaser.

5.2 Heat treatment of the tubing shall not be required under this specification.

6. Chemical Requirements

6.1 The material shall conform to the requirements as to chemical composition as prescribed in Table 1.

7. Tensile Properties

7.1 Tension tests at room temperature are not recommended as acceptance criteria under this specification since the alloys are intended for elevated-temperature service, and room-temperature tests do not have a dependable relationship to elevated-temperature properties. (Where the design of the tubing is based on an assumption of certain minimum creep-rupture properties, one of the supplementary requirements of this specification may be stipulated on the order to ascertain the ability of the material to meet the design properties.)

8. Permissible Variation in Dimensions

8.1 *Machined Tubing (Tubing Machined on Inside and Outside)*:

8.1.1 The tolerances given in Specification A 999/A 999M shall govern, except that the wall thickness shall not vary over the specified minimum wall thickness by more than 10 % or 1⁄16 in. [1.6 mm], whichever is greater. There shall be no variation under the specified minimum wall thickness.

8.2 *As-Cast Tubing (No Machining or Machined on Inside or Outside)*:

8.2.1 *Outside Diameter (For Tubes Ordered to Outside Diameter)*:

8.2.1.1 Tubes machined on the outside shall meet the requirements of Specification A 999/A 999M.

8.2.1.2 Tubes not machined on the outside shall meet the permissible variations of Table 2.

8.2.2 *Inside Diameter (For Tubes Ordered to Inside Diameter)*:

8.2.2.1 Tubes machined on the inside shall meet the requirements of Specification A 999/A 999M.

8.2.2.2 Tubes not machined on the inside shall have permissible variations as agreed upon by the purchaser and the manufacturer.

8.2.3 *Wall Thickness*—The wall thickness shall not exceed the calculated minimum as cast wall thickness by more than the limits shown in Table 3. The calculated minimum wall thickness shall be equal to the specified minimum wall thickness plus the manufacturer's allowance for "inside surface feed metal" and outside surface roughness. Upon request, the manufacturer's allowance shall be furnished to the purchaser. There shall be no variation under the calculated minimum as cast wall thickness. For tubes over 24 up to and including 54 in. [600 to 1350 mm] in diameter the "permissible variations over specified minimum as cast wall thickness" shall be agreed upon by the manufacturer and the purchaser.

8.2.4 *Length*—If definite lengths are ordered, no length of tubing shall be under the length specified and not longer than the tolerance shown in Table 4.

TABLE 2 Permissible Variations in As-Cast Outside Diameter

Specified Outside Diameter of Tubing		Permissible Plus or Minus Variations from Specified Outside Diameter	
in.	mm	in.	mm
From 2 to 4	50 to 100	0.08	2.0
Over 4 to 12	100 to 300	0.10	2.5
Over 12 to 24	300 to 600	0.12	3.0
Over 24 to 36	600 to 900	0.16	4.1
Over 36 to 54	900 to 1350	0.25	6.4

TABLE 3 Permissible Variations in As-Cast Wall Thickness

Specified Outside Diameter of Tubing		Permissible Variations over Calculated Minimum As-Cast Wall Thickness	
in.	mm	in.	mm
From 2 to 6	50 to 150	0.08	2.0
Over 6 to 12	150 to 300	0.10	2.5
Over 12 to 24	300 to 600	0.13	3.3

TABLE 4 Excess Length Tolerances for Centrifugally Cast Tubes

Outside Diameter of Tube		Permissible Excess Length	
in.	mm	in.	mm
From 2 to 12	50 to 300	¼	6.4
Over 12 to 24	300 to 600	½	13
Over 24 to 54	600 to 1350	1	25

9. Finish

9.1 *Machined Tubing*—All tubes shall be reasonably straight and free of rejectable indications. All visual irregularities shall be explored for depths. When the depth encroaches on the specified minimum wall thickness, such irregularities shall be considered rejectable indications.

9.2 *As-Cast Tubing*:

9.2.1 The outside surface shall be adequately cleaned (such as by shotblasting, sandblasting, wire brushing, grinding, or machining). The metal surface so revealed shall be visually inspected and shall be free of linear discontinuities or other imperfections that encroach on the specified minimum wall of the tube.

9.2.2 Various degrees of surface roughness occur on unmachined tubing. If a specific surface finish is required, it shall be a matter of agreement between the manufacturer and the purchaser.

9.3 *Surface Irregularities Not Classified as Rejectable*—Visual surface defects that have been explored and that do not encroach on the minimum sound wall thickness shall be blended either by machining or grinding the surface into the surrounding unaffected surface area of the tubing.

9.4 *Repair by Welding*—Repair of injurious defects by welding shall be permitted and major weld repairs shall be permitted only subject to the approval of the purchaser. Weld repairs shall be considered major if the depth of the cavity prepared for welding exceeds 20 % of the required minimum wall thickness or if the total surface area exceeds 10 in.^{2}[65 cm^2]. Defects shall be completely removed before welding. If defects are linear, complete removal shall be checked by liquid penetrant inspection (Practice E 165). Only qualified operators and procedures in accordance with Practice A 488/A 488M shall be used. All weld repairs shall be subjected to the same inspection standard as the tubing.

10. Pressure Test

10.1 All tubing shall be subjected to an internal air pressure of at least 75 psi [515 kPa] for at least 1 min either while submerged in clear water or with the entire outer surface coated with sulfur-free soap suds at the discretion of the manufacturer. In the usable portion of the tube, leaks are not permitted. If the Hydrostatic Test, Supplementary Requirement S6, is invoked, the exact details of the test and testing procedure shall be clearly defined and made a part of the Ordering Information (3.1.8).

10.2 Leaks may be repaired by welding only if such repair is approved by the purchaser.

11. Flattening Test

11.1 Flattening tests are not required since material covered by this specification is not intended to be bent, flanged, or otherwise formed.

12. Mechanical Tests Required

12.1 *Air Pressure Test*—Each length of tubing shall be subjected to the pressure test described in Section 10.

13. Certification

13.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the test results shall be furnished at the time of shipment.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 999/A 999M, the marking shall include the length, an additional symbol "S" if the tubing conforms to the supplementary requirements specified in Supplementary Requirements S1 to S11, and the heat number or manufacturer's number by which the tube can be identified, and, when as cast (see 8.2), the notation "AS CAST."

15. Keywords

15.1 alloy; centrifugal casting; high temperatures; pressure containing parts; steel tube; temperature service applications

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements may become a part of the specification when specified on the inquiry or invitation to bid, and purchase order or contract.

S1. Product Analysis

S1.1 Product analysis may be made on any length of tubing. Individual lengths failing to conform to the chemical requirements shall be rejected. For product analysis the outside surface of the tube shall be ground clean before sampling and a sample taken from this area by drilling. If drillings are taken, the drill should penetrate at least to the mid point of the tube wall, but the inner ⅛ in. [3 mm] of the tube wall shall not be included in the sample unless the tube has been bored.

S2. Short-Time, High-Temperature Tension Test

S2.1 Short-time, high-temperature tension tests shall be made from a longitudinal or transverse section cut from the end of the tubing representing each heat or lot as agreed upon between the manufacturer and the purchaser.

S2.2 The test specimen shall conform to the dimensions shown in Fig. 7 or 9 of Test Methods E 8, or as described in Practice E 151. The specimen gage diameter shall not encroach on the zone of feed metal when cut from an as-cast tube.

S2.3 The specimen shall be subjected to a short-time tension test at a temperature of 1400 °F [760 °C], 1600 °F [870 °C], 1800 °F [980 °C], or 2000 °F [1095 °C], as selected by the purchaser. During the test the temperature range shall be maintained within ± 10 °F [5.5 °C] at the selected temperature. If the temperature is not specified by the purchaser, the test shall be conducted at 1600 °F [870 °C]. Processing by heat treatment to improve the hot tensile strength of the material or specimen shall not be permitted. However, the specimens may be aged for 24 h at test temperature before testing.

S2.4 The test shall be made in accordance with Practice E 21 except that the speed of the head of the testing machine shall be so adjusted that the cross-head speed shall not exceed 0.05 in. [1.3 mm]/in. [25 mm]/min.

S2.5 The test specimens shall conform to properties agreed upon between the manufacturer and the purchaser. The values shown in Table S2 may be used as a guide.

S3. Stress Rupture Test

S3.1 The stress rupture test shall be made from a longitudinal or transverse section cut from the end of the tubing representing each heat or lot as agreed upon between the manufacturer and the purchaser.

S3.2 The conditions of testing may be specified by the purchaser as either:

S3.2.1 1600 °F [870 °C] and an initial stress of 10 000 psi [69 000 kPa] or 8000 psi [55 000 kPa], or

S3.2.2 1800 °F [980 °C] and an initial stress of 6000 psi [41 000 kPa] or 4000 psi [28 000 kPa].

S3.2.3 If not specified, the test temperature shall be 1600 °F [870 °C] and the stress 10 000 psi [69 000 kPa]. During the test the temperature range shall be maintained within ± 10 °F [5.5 °C] of the selected temperature. The test specimen shall conform to the dimensions shown in Fig. 7 or 9 of Test Methods E 8 or as described in Practice E 139. The specimen gage diameter shall not encroach on the zone of feed metal when cut from an as-cast tube.

S3.3 The stress rupture test shall be made in accordance with Practice E 139. Measurements of creep rate shall not be required. The test shall be considered complete after the specimen has endured the specified stress for the minimum acceptable time. Processing by heat treatment to improve the creep resistance of the material or specimen shall not be permitted. However, the specimens may be aged for 24 h at test temperature before testing.

TABLE S2 Minimum Elevated Temperature Tensile Strength and Elongation Values for Centrifugal Cast Heat-Resistant Alloy Tubing

Grade	1400 °F [760 °C]		1600 °F [870 °C]		1800 °F [980 °C]		2000 °F [1095 °C]	
	Tensile Strength, psi [kPa]	Elongation, %	Tensile Strength, psi [kPa]	Elongation, %	Tensile Strength, psi [kPa]	Elongation, %	Tensile Strength, psi [kPa]	Elongation, %
HC30	5300 [36000]	40	2960 [20400]	50	1600 [11000]	40		
HD50	7450 [51400]		2580 [17800]		910 [6200]			
HF30[A]	26000 [180000]	7.0	14500 [100000]	9.0	(not for use above 1600 °F)			
HH30			7650 [52700]	12.0	3510 [24200]	16.0		
HH33[A]			20000 [138000]	8.0	8200 [56000]	12.0	4000 [28000]	20.0
H135[A]			20000 [138000]	8.0	8200 [56000]	12.0		
HK30	26000 [180000]		14000 [97000]	9.0	7500 [52000]	18.0	3600 [25000]	24.0
HK40	29000 [200000]	7.0	16500 [114000]	6.0	8800 [61000]	15.0	4200 [29000]	22.0

[A] If these values are to be met, manufacturing control should ensure that these compositions contain a minimal amount of ferrite. See Supplementary Requirement S5.

S3.4 The test specimens shall conform to properties agreed upon between the manufacturer and the purchaser. The values shown in Table S3 may be used as a guide.

S4. Room-Temperature Tension Test

S4.1 The manufacturer shall perform one tension test at room temperature on material from each heat. The properties to be met are a matter of agreement between the purchaser and the manufacturer.

S5. Control of Ferrite

S5.1 The amount of ferrite in the metal structure of Alloys HF30, HH33, and HI35 shall be controlled to limit the magnetic permeability to a maximum of 1.05.

S5.2 Test specimens for magnetic permeability measurements to determine delta ferrite content shall be in accordance with the applicable specimen requirements of Test Methods A 342/A 342M. Apparatus to perform the magnetic permeability measurements shall be in accordance with the requirements of Test Methods A 342/A 342M (Section 1, 2, or 3) whether individually constructed or obtained commercially. Prior to testing the test specimen material shall be heated in air to 2000 °F [1095 °C], held within ± 25 °F [15 °C] range of this temperature for 24 h, and then quenched in water. After quenching, all scale and superficial oxidized metal shall be removed from the specimen prior to testing.

S6. Hydrostatic Test

S6.1 Hydrostatic tests shall be performed in accordance with the Hydrostatic Test Requirements Section of Specification A 999/A 999M or as agreed upon between the manufacturer and the purchaser.

S7. Metal Structure and Etching Tests

S7.1 Etching tests (Note S1) shall be made on transverse or longitudinal sections from any tube, and shall show sound and reasonably uniform material within the specified sound wall area, free of injurious laminations and similar objectionable defects. If the specimen from either end of any length shows objectionable defects, one retest shall be permitted from that end. If this fails, the length shall be cut back until sound metal is obtained.

S7.2 The nature of these heat-resistant alloys produced by the centrifugal process may cause them to exhibit a difference in grain size from length to length and within an individual length. This difference in grain size shall not be cause for rejection.

NOTE S1—It is recommended that the macroetching test procedures described in Test Method E 340 be followed.

TABLE S3 Minimum Time to Rupture Values for Centrifugally Cast Heat-Resistant Alloy Tubing

Grade	Minimum Rupture Life, h			
	1600 °F [870 °C] 10 000 psi [69000 kPa]	1600 °F [870 °C] 8000 psi [55000 kPa]	1800 °F [980 °C] 6000 psi [41000 kPa]^2	1800 °F [980 °C] 4000 psi [28000 kPa]
HF30	6.0	18		
HH33[A]	5.0	17	3.0	20
HK30	7.0	24	4.0	34
HK40	25		11	
HK50	47		20	

[A] Manufacturing control should ensure that this composition contain a minimal amount of ferrite. See Supplementary Requirement S5.

S8. Photomicrographs

S8.1 The manufacturer shall furnish one photomicrograph at 100 diameters from a specimen of tubing in the as-finished condition representing each heat. Such photomicrographs shall be suitably identified as to tubing size, wall thickness, and heat number. No photomicrographs for the individual pieces purchased shall be required except as specified in Supplementary Requirement S9. Such photomicrographs are for information only, to show the actual metal structure of the tubing as furnished.

S9. Photomicrographs for Individual Pieces

S9.1 In addition to the photomicrographs required in accordance with Supplementary Requirement S8, photomicrographs shall be furnished from one or both ends of a length of tubing. All photomicrographs required shall be properly identified as to heat number, size, and wall thickness of tubing from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of tubing it represents.

S10. Radiographic Inspection

S10.1 The turned and bored tubing shall be examined for internal defects by means of X rays or gamma rays. The inspection procedure shall be in accordance with the Practice E 94 or Method E 142 as agreed upon between the manufacturer and the purchaser. The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser. A specification which may be used as a basis for such agreement is Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components (Radiographic Inspection Method, SP-54) of the Manufacturer's Standardization Society of the Valve and Fittings Industry.

S11. Liquid Penetrant Inspection

S11.1 Liquid penetrant inspection shall be performed only on those areas of the tubing which have been suitably prepared for this type of inspection by grinding, machining, polishing, or other processing. The number of pieces, the areas to be inspected, the procedure to be used, and the standards of acceptability shall be agreed upon between the manufacturer and the purchaser.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 608/A 608M – 02, that may impact the use of this specification. (Approved September 1, 2006)

(*1*) Replaced Specification A 530/A 530M with Specification A 999/A 999M throughout.

(*2*) Revised Note S1 to replace *Metals Handbook*, American Society for Metals, 1948 edition, p. 389 with Test Method E 340.

Designation: A 595/A 595M – 06

Standard Specification for Steel Tubes, Low-Carbon or High-Strength Low-Alloy, Tapered for Structural Use[1]

This standard is issued under the fixed designation A 595/A 595M; 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*

1.1 This specification covers three grades of seam-welded, round, tapered steel tubes for structural use. Grades A and B are of low-carbon steel or high-strength low-alloy steel composition and Grade C is of weather-resistant steel composition.

1.2 This tubing is produced in welded sizes in a range of diameters from 2 3⁄8 to 30 in. [60 to 762 mm] inclusive. Wall thicknesses range from 0.1046 to 0.375 in. [2.66 to 9.53 mm]. Tapers are subject to agreement with the manufacturer.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used indepedently of the other. Combining values from the two systems may result in non-conformance with the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 588/A 588M Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, with Atmospheric Corrosion Resistance

A 606 Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

G 101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels

3. Ordering Information

3.1 The inquiry and order should indicate the following:

3.1.1 Large and small diameters (in.) [mm], length (ft) [m], wall thickness (in.) [mm], taper (in./ft) [mm/m];

3.1.2 (see Table 1 and Table 2);

3.1.3 Extra test material requirements, if any; and

3.1.4 Supplementary requirements, if any.

4. General Requirements for Delivery

4.1 Required date of shipment or date of receipt, and

4.2 Special shipping instructions, if any.

5. Manufacture

5.1 Tube steel shall be hot-rolled aluminum-semikilled or fine-grained killed sheet or plate manufactured by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

5.2 Tubes shall be made from trapezoidal sheet or plate that is preformed and then seam welded. Tubes shall be brought to final size and properties by roll compressing cold on a hardened mandrel.

6. Chemical Composition

6.1 Steel shall conform to the requirements for chemical composition given in Tables 1 and 3. Chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

6.2 For Grade C material, the atmospheric corrosion-resistance index, calculated on the basis of the chemical composition of the steel, as described in Guide G 101, shall be 6.0 or higher.

NOTE 1—The user is cautioned that the Guide G 101 predictive equation for calculation of an atmospheric corrosion-resistance index has been verified only for the composition limits stated in that guide.

6.3 When required by the purchase order, the manufacturer shall supply guidance concerning corrosion resistance that is satisfactory to the purchaser.

7. Mechanical Properties

7.1 *Tension Test*:

7.1.1 *Requirements*—The material, as represented by the test specimens, shall conform to the requirements as to tensile properties given in Table 2.

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved March 1, 2006. Published March 2006. Originally approved in 1969. Last previous edition approved in 2004 as A 595 – 04a.

[2] 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.

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

TABLE 1 Chemical Requirements

Elements	Composition by Heat Analysis, %												
	Grade A				Grade B				Grade C				
	Carbon Steel	HSLA SS	HSLAS Cl1	HSLAS Cl2	Carbon Steel	HSLA SS	HSLAS Cl1	HSLAS Cl2	A 606	A 588/A	A 588/B	A 588/C	A 588/K
Carbon	0.015–0.25	0.25 max	0.23 max	0.15 max	0.015–0.25	0.25 max	0.26 max	0.15 max	0.22 max	0.19 max	0.20 max	0.15 max	0.17 max
Manganese	0.30–0.90	1.35 max	1.35 max	1.35 max	0.40–1.35	1.35 max	1.50 max	1.50 max	1.25 max	0.80–1.25	0.75–1.35	0.80–1.35	0.50–1.20
Phosporous	0.035 max	0.035 max	0.04 max	0.04 max	0.035 max	0.035 max	0.04 max	0.04 max	[A]	0.04 max	0.04 max	0.04 max	0.04 max
Sulfur	0.035 max	0.04 max	0.04 max	0.04 max	0.035 max	0.04 max	0.04 max	0.04 max	0.04 max	0.05 max	0.05 max	0.05 max	0.05 max
Silicon	0.040 max[B]	0.040 max[B]	0.040 max[B]	0.040 max[B]	0.040 max[B]	0.040 max[B]	0.040 max[B]	0.040 max[B]	[A]	0.30–0.65	0.15–0.50	0.15–0.40	0.25–0.50
Copper[C,D]	...	0.20 max	0.20 max	0.20 max	...	0.20 max	0.20 max	0.20 max	[A]	0.25–0.40	0.20–0.40	0.20–0.50	0.30–0.50
Chromium[C,E]	...	0.15 max	0.15 max	0.15 max	...	0.15 max	0.15 max	0.15 max	[A]	0.40–0.65	0.40–0.70	0.30–0.50	0.40–0.70
Nickel[C]	...	0.20 max	0.20 max	0.20 max	...	0.20 max	0.20 max	0.20 max	[A]	0.40 max	0.50 max	0.25–0.50	0.40 max
Molybdenum[C,E]	...	0.06 max	0.06 max	0.06 max	...	0.06 max	0.06 max	0.06 max	...	[A]	[A]	[A]	0.10 max
Vanadium[F]	...	0.008 max	0.01 min	0.01 min	...	0.008 max	0.01 min	0.01 min	...	0.02–0.10	0.01–0.10	0.01–0.10	[A]
Columbium[F]	...	0.008 max	0.005 min	0.005 min	...	0.008 max	0.005 min	0.005 min	...	[A]	[A]	[A]	0.005–0.05
Nitrogen	...	[A]	[A]	[A]	...	[A]	[A]	[A]	...	...	...	...	...
Aluminum[B]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	...	...	...	...	...

[A] There is no limit; however, the analysis shall be reported.

[B] Silicon or silicon in combination with aluminum must be sufficient to ensure uniform mechanical properties. Their sum shall be greater than or equal to 0.020 %.

[C] For HSLA steels the sum of copper, nickel, chromium, and molybdenum shall not exceed 0.50 % on heat analysis. When one of these elements are specified by the purchaser, the sum does not apply, in which case only the individual limits of the remaining elements shall apply.

[D] For HSLA steels when copper is specified, the copper limit is a minimum requirement. When copper steel is not specified, the copper limit is a maximum requirement.

[E] For SS steel the sum of chromium and molybdenum shall not exceed 0.16 % on heat analysis. When one or more of these elements are specified by the purchaser, the sum does not apply, in which case the individual limit on the remaining unspecified element shall apply.

[F] For HSLA steels vanadium and columbium minimums may be satisfied separately or by combining their values, in which event the sum shall exceed the combined minimums.

TABLE 2 Tensile Requirements

	Grade A	Grade B	Grade C
Yield point, min, ksi [MPa]	55 [380]	60 [410]	60 [410]
Ultimate tensile strength, min, ksi [MPa]	65 [450]	70 [480]	70 [480]
Elongation in 2 in. [50 mm], min %	23	21	21

7.1.2 *Number of Tests*:

7.1.2.1 For coil—One or more tension tests as defined in Table 2 shall be made from the large end of one tube on each 100, or fewer, tubes produced from each coil in the applicable thickness class (see Table 4).

7.1.2.2 For plate—One or more tension tests as defined in Table 2 shall be made from the large end of one tube on a lot produced from a single heat of plate product of uniform thickness.

7.1.3 *Test Locations and Orientations*—Samples shall be taken at least 1 in. [25 mm] from the longitudinal seam weld.

7.1.4 *Test Method*:

7.1.4.1 Tension tests shall be made in accordance with Test Methods and Definitions A 370. The yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen or to a total extension of 0.5% of the gage length under load shall be determined in accordance with Test Methods and Definitions A 370.

7.1.4.2 The ultimate tensile strength shall be determined in accordance with the Tensile Strength of Test Methods and Definitions A 370.

7.1.5 Each test shall be identified as to the heat number of the basic material.

8. Dimensions and Tolerances

8.1 *Length*—The length shall be the specified length with a tolerance of +¾ in. [19 mm] or −¼ in. [6 mm].

8.2 *Diameter*—The outside diameter shall conform to the specified dimensions with a tolerance of ±1⁄16 in. [2 mm] as measured by girthing.

8.3 *Wall Thickness*—The tolerance for wall thickness exclusive of the weld area shall be +10 % or −5 % of the nominal wall thickness specified.

8.4 *Straightness*—The permissible variation for straightness of the tapered tube shall be 0.2 % or less of the total length.

9. Rework and Retreatment

9.1 In case any test fails to meet the requirements of Section 7, the manufacturer may elect to retreat, rework, or otherwise eliminate the condition responsible for failure to meet the specified requirements. Thereafter the material remaining from the respective class originally represented may be tested and shall comply with all requirements of this specification.

9.2 Imperfections in the outer surface, such as cracks, scabs, or excessive weld projections, shall be classed as injurious defects when their depth or projection exceeds 15 % of the wall thickness or when the imperfections materially affect the appearance of the tube.

9.2.1 Injurious defects having a depth not in excess of 33⅓ % of the specified wall thickness may be repaired by welding subject to the following conditions: (*1*) scabs shall be completely removed by chipping or grinding to sound metal, and (*2*) the repair weld shall be made using suitable electrodes.

9.2.2 Excessive projected weld metal shall be removed to produce a commercial finish.

10. Inspection

10.1 Inspection of material shall be made as agreed upon between the purchaser and the seller as part of the purchase contract.

11. Rejection and Rehearing

11.1 Each length of tubing received from the manufacturer may be inspected by the purchaser, and if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

11.2 Tubing found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such tubing shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

12. Certification and Reports

12.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the chemical and tension tests shall be furnished.

13. Product Marking

13.1 Each tapered tube shall be legibly marked by rolling, die stamping, ink printing, or paint stenciling to show the following information: thickness, taper, large diameter, small diameter, length, and the specification number, Grade A, B, or C.

13.2 *Bar Coding*—In addition to the requirements in 13.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

14. Keywords

14.1 carbon steel tube; steel tube

TABLE 3 Chemical Requirements

Elements	Composition by Product Analysis, %												
	Grade A				Grade B				Grade C				
	Carbon Steel	HSLA SS	HSLAS Cl1	HSLAS Cl2	Carbon Steel	HSLA SS	HSLAS Cl1	HSLAS Cl2	A 606	A 588/A	A 588/B	A 588/C	A 588/K
Carbon	0.012–0.29	0.29 max	0.27 max	0.18 max	0.012–0.29	0.29 max	0.29 max	0.18 max	0.26 max	0.23 max	0.24 max	0.18 max	0.21 max
Manganese	0.26–0.94	1.40 max	1.40 max	1.40 max	0.35–1.40	1.40 max	1.40 max	1.40 max	1.3 max	0.72–1.35	0.67–1.45	0.72–1.45	0.42–1.30
Phosphorous	0.045 max	0.045 max	0.05 max	0.05 max	0.45 max	0.45 max	0.05 max	0.05 max	[A]	0.05 max	0.05 max	0.05 max	0.05 max
Sulfur	0.045 max	0.05 max	0.05 max	0.05 max	0.45 max	0.05 max	0.05 max	0.05 max	0.06 max	0.06 max	0.06 max	0.06 max	0.06 max
Silicon	0.040 max[B]	0.040 max[B]	0.040 max[B]	0.040 max[B]	0.40 max[B]	0.40 max[B]	0.40 max[B]	0.40 max[B]	[A]	0.25–0.70	0.15–0.60	0.13–0.43	0.20–0.55
Copper	...	0.22 max	0.22 max	0.22 max	...	0.22 max	0.22 max	0.22 max	[A]	0.22–0.43	0.17–0.43	0.17–0.53	0.27–0.53
Chromium	...	0.19 max	0.19 max	0.19 max	...	0.19 max	0.19 max	0.19 max	[A]	0.36–0.69	0.36–0.74	0.26–0.54	0.36–0.74
Nickel	...	0.23 max	0.23 max	0.23 max	...	0.23 max	0.23 max	0.23 max	[A]	0.43 max	0.53 max	0.22–0.53	0.43 max
Molybdenum	...	0.07 max	0.07 max	0.07 max	...	0.07 max	0.07 max	0.07 max	...	[A]	[A]	[A]	0.11 max
Vanadium[C]	...	0.018 max	0.00 min	0.00 min	...	0.018 max	0.00 min	0.00 min	...	0.01–0.11	0.00–0.11	0.00–0.11	[A]
Columbium[C]	...	0.018 max	0.00 min	0.00 min	...	0.018 max	0.00 min	0.00 min	...	[A]	[A]	[A]	0.055 max
Nitrogen	...	[A]	[A]	[A]	...	[A]	[A]	[A]	...	...	...	...	...
Aluminum[B]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	[A]	...	...	...	...	...

[A] There is no limit; however, the analysis shall be reported.

[B] Silicon or silicon in combination with aluminum must be sufficient to ensure uniform mechanical properties. Their sum shall be greater than or equal to 0.020 %.

[C] For HSLA steels vanadium and columbium minimums may be satisfied separately or by combining their values, in which event the sum shall exceed the combined minimums.

TABLE 4 Thickness Class

Class	Thickness	
	in.	mm
1	0.1046 through 0.140	2.66 through 3.56
2	0.141 through 0.190	3.58 through 4.83
3	0.191 through 0.280	4.85 through 7.11
4	0.281 through 0.375	7.14 through 9.53

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 595 – 04a, that may impact the use of this specification. (Approved March 1, 2006)

(*1*) Revised Sections 1, 3, 7, and 8 to include rationalized SI units, creating a combined standard.

(*2*) Revised the SI Yield point in Table 2 to 425 MPa, SI elongation to [50 mm], and elongation to whole numbers, not tenths of a percent.

Standard Specification for Seamless and Welded Carbon Steel Water-Well Pipe[1]

This standard is issued under the fixed designation A 589/A 589M; 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*

1.1 This specification covers four specific types of plain end or threaded and coupled carbon steel pipe for use in water wells.

1.2 Each type of water well pipe shall conform to the following methods of manufacture and grade as specified on the purchase order:

1.2.1 *Type I, Drive Pipe*—Seamless or electric-resistance-welded, Grades A and B.

1.2.2 *Type II, Water-Well Reamed and Drifted Pipe*—Seamless or electric-resistance-welded, Grades A and B, or furnace-butt welded.

1.2.3 *Type III, Driven Well Pipe*—Seamless or electric-resistance-welded, Grades A and B, or furnace-butt welded.

1.2.4 *Type IV, Water-Well Casing Pipe*—Seamless or electric-resistance-welded, Grades A and B, or furnace-butt welded.

1.3 The values stated in either inch-pound units or in SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values in each system are not exact equivalents; therefore, each system is to be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

NOTE 1—The dimensionless designator NPS (nominal pipe size) and DN (Nominal Diameter) have been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 865 Specification for Threaded Couplings, Steel, Black or Zinc-Coated (Galvanized) Welded or Seamless, for Use in Steel Pipe Joints

2.2 *API Standard:*

5L Specification for Line Pipe[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *defect*—an imperfection of sufficient size or magnitude to be cause for rejection.

3.1.2 *imperfection*—any discontinuity or irregularity found in the pipe.

4. Ordering Information

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

4.1.1 Quantity (feet or number of lengths),

4.1.2 Name of material or type number (see 1.2),

4.1.3 Method of manufacture (furnace-butt welded, seamless, or electric-resistance-welded),

4.1.4 Grade (A or B for seamless or electric-resistance welded),

4.1.5 Finish (black or galvanized),

4.1.6 Dimensions (NPS or outside diameter and wall thickness, or both, for Types I, II, and III. Outside diameter and wall thickness for Type IV),

4.1.7 End finish (plain end or threaded and coupled),

4.1.8 Coupling class for Type III (standard pipe, line pipe, or reamed and drifted pipe coupling),

4.1.9 Coupling make-up (hand tight or power tight),

4.1.10 Length (required random range length or special lengths),

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved March 1, 2006. Published April 2006. Originally approved in 1968. Last previous edition approved in 2001 as A 589 – 96(2001).

[2] 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.

[3] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005.

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

4.1.11 Specification designation, and
4.1.12 Special requirements.

5. Materials and Manufacture

5.1 The steel for both seamless and welded pipe shall be made by one of the following processes: open-hearth, electric-furnace, or basic-oxygen.

5.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

6. Chemical Composition

6.1 The steel shall conform to the following requirements as to chemical composition:

Phosphorus, max, %	0.050
Sulfur, max, %	0.060

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentage of the elements specified in 6.1. When requested by the purchaser, the chemical composition thus determined shall be reported to the purchaser, and shall conform to the requirements specified in 6.1.

8. Product Analysis

8.1 An analysis may be made by the purchaser on two lengths of pipe from each lot of 500 lengths, or fraction thereof. Samples for chemical analysis and the methods of analysis shall conform to the requirements of Test Methods, Practices, and Terminology A 751. The chemical composition thus determined shall conform to the requirements specified in 6.1.

8.2 If the analysis of either pipe does not conform to the requirements of 6.1, analysis shall be made on additional lengths of pipe of double the original number from the same lot, each of which shall conform to the requirements specified.

9. *Tensile Requirements*—Tensile Requirements

9.1 The material shall conform to the requirements as to tensile properties specified in Table 1.

TABLE 1 Tensile Requirements

	Butt Welded	Grade A	Grade B
Tensile strength, min, psi (MPa)	48 000 (330)	48 000 (330)	60 000 (415)
Yield strength, min, psi (MPa)	30 000 (205)	30 000 (205)	35 000 (240)
Elongation in 2 in.	A	A	A

A The minimum elongation in 2 in. (50.8 mm) shall be that determined by the following equation:

$$e = 625\ 000\, A^{0.2} / U^{0.9}$$

where:

e = minimum elongation in 2 in. (50.8 mm) in percent rounded to the nearest 0.5 %.
A = cross-sectional area of the tension test specimen in square inches, based on specified outside diameter or nominal specimen width and specified wall thickness rounded to the nearest 0.01 in.2 If the area thus calculated is greater than 0.75 in.2, then the value 0.75 shall be used.
U = specified tensile strength, psi.

9.2 The test specimen taken across the weld shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe ordered. This test is not required for pipe under 8 in. [DN 200] in outside diameter.

10. Dimensions, Weights, and Permissible Variations

10.1 The dimensions and weights of all types of pipe included in this specification are listed in Tables 2-17:

Type	Tables
I, Drive Pipe	Table 2, Table 3, Table 4, Table 5
II, Reamed and Drifted Pipe	Table 6, Table 7, Table 8, Table 9
III, Driven Well Pipe	Table 10, Table 11, Table 12, Table 13
IV, Water-Well Casing Pipe	Table 14, Table 15, Table 16, Table 17

10.2 *Permissible Variations in Weight and Dimensions*:

10.2.1 *Weight*—The weight of all types of pipe included in this specification shall vary not more than ± 5 % from that prescribed. The weight tolerance for pipe NPS 4 [DN 100] and under may be determined from the weight of the customary lifts of pipe as produced for shipment, divided by the number of feet of pipe in the lift. For pipe over NPS 4 [DN 100], where individual lengths may be weighed, the weight is applicable to the individual length.

10.2.2 *Outside Diameter*—For pipe NPS 1½ [DN 40] and under, the outside diameters shall vary not more than 1⁄64 in. [0.4 mm] from the outside diameter specified. For pipe NPS 2 [DN 50] and over, the outside diameter shall vary not more than ± 1 % from the size specified.

10.2.3 *Inside Diameter*—For Type II pipe, the inside diameter at any point, shall permit passage of a drift pin having a length and diameter as indicated in Table 6, Table 7, and Table 18.

10.2.4 *Thickness*—The minimum wall thickness shall be not more than 12.5 % under the nominal wall thickness specified.

10.3 *Lengths*:

10.3.1 Unless otherwise specified on the purchase order, pipe lengths shall be in accordance with the following regular practice:

10.3.1.1 Types I, II, and IV pipe may be furnished in single random lengths of 16 to 22 ft [4.9 to 6.7 m].

10.3.1.2 Type III pipe may be furnished in a random range from 3 to 6 ft [0.9 to 1.8 m] or 6 to 10 ft [1.8 to 3.0 m] as specified.

10.3.2 Random lengths other than indicated in 10.3.1 and cut lengths, shall be subject to negotiation and shall be indicated on the purchase order.

11. Ends

11.1 When ordered with plain ends, the pipe shall be furnished to the following practice unless otherwise specified.

11.1.1 *NPS 1½ [DN 40] and smaller*——Unless otherwise specified on the purchase order, end finish shall be at the option of the manufacturer.

TABLE 2 Dimensions, Weights, and Test Pressures for Drive Pipe (Inch-Pound Units)

NPS Desig-nator	Weight per Foot, lb/ft		Wall Thick-ness, in.	Diameters, in.		No. of Threads per Inch	Couplings			Test Pressures, psi	
	Nominal Threads and Coup-lings	Calculated Plain Ends		Outside	Inside		Length, in.	Outside Diameter, in.	Calculated Weight, lb	Grade A	Grade B
6	19.45	18.97	0.280	6.625	6.065	8	5⅛	7.290	13.35	1200	1300
8	25.55	24.70	0.277	8.625	8.071	8	6⅛	9.625	26.89	1200	1300
8	29.35	28.55	0.322	8.625	7.981	8	6⅛	9.625	26.89	1300	1600
8	32.40	31.27	0.354	8.625	7.917	8	6⅛	9.625	26.89	1300	1600
10	32.75	31.20	0.279	10.750	10.192	8	6⅝	11.750	36.05	940	1100
10	35.75	34.24	0.307	10.750	10.136	8	6⅝	11.750	36.05	1000	1200
10	41.85	40.48	0.365	10.750	10.020	8	6⅝	11.750	36.05	1200	1400
12	45.45	43.77	0.330	12.750	12.090	8	6⅝	14.000	52.72	950	1100
12	51.15	49.56	0.375	12.750	12.000	8	6⅝	14.000	52.72	1100	1200
14 D	57.00	54.57	0.375	14.000	13.250	8	7⅛	15.000	50.22	950	1100
16 D	65.30	62.58	0.375	16.000	15.250	8	7⅛	17.000	57.17	850	1000

TABLE 3 Dimensions, Weights, and Test Pressures for Drive Pipe (SI Units)

DN Desig-nator	Weight per Foot, kg/m		Wall Thick-ness, mm	Diameters, mm		No. of Threads per 25.4 mm	Couplings			Test Pressures, kPa	
	Nominal Threads and Coup-lings	Calculated Plain Ends		Outside	Inside		Length, mm	Outside Diameter, mm	Calculated Weight, kg/m	Grade A	Grade B
150	28.94	28.23	7.11	168.3	154.1	8	130.18	185.17	19.86	8300	9 000
200	38.02	36.75	7.04	219.1	205.0	8	155.58	244.48	40.01	8300	9 000
200	43.67	42.48	8.18	219.1	202.7	8	155.58	244.48	40.01	9000	11 000
200	48.21	46.53	8.99	219.1	201.1	8	155.58	244.48	40.01	9000	11 000
250	48.73	46.43	7.09	273.1	258.9	8	168.28	298.45	53.64	6500	7 600
250	53.20	50.95	7.80	273.1	257.5	8	168.28	298.45	53.64	6900	8 300
250	62.27	60.23	9.27	273.1	254.5	8	168.28	298.45	53.64	8300	9 700
300	67.63	65.13	8.38	323.9	307.1	8	168.28	355.60	78.45	6600	7 600
300	76.11	73.75	9.53	323.9	304.8	8	168.28	355.60	78.45	7600	8 300
350	84.82	81.20	9.53	355.6	336.6	8	180.98	381.00	74.73	6600	7 600
400	97.17	93.12	9.53	406.4	387.4	8	180.98	431.80	85.07	5900	6 900

TABLE 4 Basic Threading Data for Drive Pipe (Inch-Pound Units)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pipe				Threads[A]			Coupling						
NPS Desig-nator	Out-side Diam-eter, in.	Num-ber per in.	Length, End of Pipe to Hand-tight Plane, in.	Effec-tive Length, in.	Total Length, End of Pipe to Vanish Point, in.	Pitch Diameter at Hand-tight Plane, in.	Outside Diameter, in.	Length, in.	Diameter of Recess, in.	Depth of Recess, in.	Length, Face of Coupling to Hand-tight Plane, in.	Width of Bearing Face, in.	Hand-tight Standoff, Threads
	D^B		$L_1{}^B$	$L_2{}^B$	$L_4{}^B$	$E_1{}^B$	W^B	$N_L{}^B$	Q^B	q^B	M^B	b^B	A^B
6	6.625	8	1.093	1.973	2.438	6.51375	7.390	5⅛	6.719	⅜	0.595	¼	6
8	8.625	8	1.593	2.473	2.938	8.51375	9.625	6⅛	8.719	⅜	0.595	¼	6
10	10.750	8	1.843	2.723	3.188	10.63875	11.750	6⅝	10.844	⅜	0.595	⅜	6
12	12.750	8	1.843	2.723	3.188	12.63875	14.000	6⅝	12.844	⅜	0.595	⅜	6
14 D	14.000	8	2.093	2.973	3.438	13.88875	15.000	7⅛	14.094	⅜	0.595	⅜	6
16 D	16.000	8	2.093	2.973	3.438	15.88875	17.000	7⅛	16.094	⅜	0.595	⅜	6

[A] Taper of threads is 3⁄16 in./ft on diameter for all sizes.
[B] See Fig. 1.

11.1.2 *NPS 2 [DN 50] and larger*—Unless otherwise specified on the purchase order, end finish shall be plain end beveled to an angle of 30° + 5° and −0°, as measured from a line drawn perpendicular to the axis of the pipe, with a root face of 1⁄16 in. [1.6 mm] ± 1⁄32 in. [0.8 mm].

11.2 When ordered threaded and coupled, each length of water well pipe shall be furnished with threaded ends and provided with a suitable coupling applied handling-tight. If couplings are required to be made up power tight, this shall be indicated on the purchase order.

TABLE 5 Basic Threading Data for Drive Pipe (SI Units)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pipe		Threads[A]					Coupling						
DN Desig-nator	Out-side Diam-eter, mm	Num-ber per 25.4 mm	Length, End of Pipe to Hand-tight Plane, mm	Effec-tive Length, mm	Total Length, End of Pipe to Vanish Point, mm	Pitch Diameter at Hand-tight Plane, mm	Outside Diameter, mm	Length, mm	Diameter of Recess, mm	Depth of Recess, mm	Length, Face of Coupling to Hand-tight Plane, mm	Width of Bearing Face, mm	Hand-tight Standoff, Threads, mm
	D[B]		L_1[B]	L_2[B]	L_4[B]	E_1[B]	W[B]	N_L[B]	Q[B]	q[B]	M[B]	b[B]	A[B]
150	168.28	8	27.76	50.11	61.93	165.45	187.71	130.18	170.66	9.53	15.11	6.35	6
200	219.08	8	40.46	62.81	74.63	216.25	244.48	155.58	221.46	9.53	15.11	6.35	6
250	273.05	8	46.81	69.16	80.98	270.22	298.45	168.28	275.44	9.53	15.11	9.53	6
300	323.85	8	46.81	69.16	80.98	321.02	355.60	168.28	326.24	9.53	15.11	9.53	6
350	355.60	8	53.16	75.51	87.33	352.77	381.00	180.98	357.99	9.53	15.11	9.53	6
400	406.40	8	53.16	75.51	87.33	403.57	431.80	180.98	408.79	9.53	15.11	9.53	6

[A] Taper of threads is 4.8 mm/305 mm on diameter for all sizes.
[B] See Fig. 1.

TABLE 6 Dimensions, Weights, and Test Pressures for Water-Well Reamed and Drifted Pipe (Inch-Pound Units)

NPS Designator	Weight per Foot, lb/ft		Wall Thickness, in.	Diameters, in.		No. of Threads per Inch	Couplings			Test Pressures, psi		
	Nominal Threads and Coup-lings	Calculat-ed Plain Ends		Out-side	In-side[A]		Length, in.	Outside Diam-eter, in.	Calcu-lated Weight, lb	Butt Weld-ed	Grade A	Grade B
1	1.70	1.68	0.133	1.315	1.049	11½	2¾	1.576	0.52	700	700	700
1¼	2.30	2.27	0.140	1.660	1.380	11½	2¾	1.900	0.60	1000	1000	1100
1½	2.75	2.72	0.145	1.900	1.610	11½	2¾	2.200	0.84	1000	1000	1100
2	3.75	3.65	0.154	2.375	2.067	11½	3⅜	2.750	1.58	1000	2300	2500
2	4.00	3.94	0.167	2.375	2.041	11½	3⅜	2.750	1.58	1000	2500	2500
2½	5.90	5.79	0.203	2.875	2.469	8	3 15/16	3.250	2.32	1000	2500	2500
3	7.70	7.58	0.216	3.500	3.068	8	4 1/16	4.000	3.80	1000	2200	2500
3½	9.25	9.11	0.226	4.000	3.548	8	4 3/16	4.625	5.53	1200	2000	2400
4	11.00	10.79	0.237	4.500	4.026	8	4 5/16	5.200	7.14	1200	1900	2200
5	15.00	14.62	0.258	5.563	5.047	8	4½	6.296	9.57	1200	1700	1900
6	19.45	18.97	0.280	6.625	6.065	8	4 11/16	7.390	12.32	...	1500	1800
8	29.35	28.55	0.322	8.625	7.981	8	5 1/16	9.625	22.35	...	1300	1600
10	41.85	40.48	0.365	10.750	10.020	8	5 9/16	11.750	30.61	...	1200	1400
12	51.15	49.56	0.375	12.750	12.000	8	5 15/16	14.000	47.96	...	1100	1200

[A] Drift pin dimensions (see Table 18)

11.3 The basic thread dimensions for each type of water well pipe are shown in Table 4, Table 5, Table 8, Table 9, Table 12, Table 13, Table 16, and Table 17. An illustration of the joint of each type of water well pipe is shown in Figs. 1-4.

11.4 For Type III pipe, the threads on the pipe ends are interchangeable with either the standard pipe coupling, the reamed and drifted pipe coupling, or the API line pipe coupling. Orders for this class material shall indicate the coupling class desired.

11.4.1 Standard pipe couplings shall be manufactured in accordance with Specification A 865.

11.4.2 Line pipe couplings shall be manufactured in accordance with API 5L Specification for Line Pipe.

11.5 The threads on the pipe ends not protected by a coupling shall be suitably protected against damage in normal handling and transit conditions.

11.6 The length of the pipe shall be measured to the outer face of the coupling.

12. Finish

12.1 The finished pipe shall be reasonably straight and free of defects. Any imperfection that exceeds 12½ % of the nominal wall thickness, or violates minimum wall shall be considered a defect.

12.2 The pipe ends shall be free of burrs. The zinc coating on galvanized pipe shall be free of voids or excessive roughness.

13. Galvanized Pipe

13.1 For the types of water well pipe required with galvanized coating, such coating shall comply with the requirements of the latest revision of Specification A 53/A 53M.

14. Number of Tests

14.1 One longitudinal or transverse tension test of seamless and welded pipe, and in addition, one transverse weld test for electric-welded pipe NPS 8 [DN 200] and larger, shall be made

TABLE 7 Dimensions, Weights, and Test Pressures for Water-Well Reamed and Drifted Pipe (SI Units)

DN Designator	Weight per Foot, kg/m		Wall Thickness, mm	Diameters, mm		No. of Threads per 25.4 mm	Couplings			Test Pressures, kPa		
	Nominal Threads and Couplings	Calculated Plain Ends		Outside	Inside[A]		Length, mm	Outside Diameter, mm	Calculated Weight, Kg	Butt Welded	Grade A	Grade B
25	2.53	2.50	3.38	33.4	26.6	11½	69.85	40.03	0.77	4900	4 800	4 800
32	3.42	3.38	3.56	42.2	35.1	11½	69.85	48.26	0.89	6900	6 900	7 600
40	4.09	4.05	3.68	48.3	40.9	11½	69.85	55.88	1.25	6900	6 900	7 600
50	5.58	5.43	3.91	60.3	52.5	11½	85.73	69.85	2.35	6900	15 900	17 200
50	5.95	5.86	4.24	60.3	51.8	11½	85.73	69.85	2.35	6900	17 200	17 200
65	8.78	8.62	5.16	73.0	62.7	8	100.01	82.55	3.45	6900	17 200	17 200
80	11.46	11.28	5.49	88.9	77.9	8	103.19	101.60	5.65	6900	15 200	17 200
90	13.76	13.56	5.74	101.6	90.1	8	106.36	117.48	8.23	8300	13 800	16 500
100	16.37	16.06	6.02	114.3	102.3	8	109.54	132.08	10.62	8300	13 100	15 200
125	22.32	21.75	6.55	141.3	128.2	8	114.30	159.92	14.24	8300	11 700	13 100
150	28.94	28.23	7.11	168.3	154.1	8	119.06	187.71	18.33	...	10 300	12 400
200	43.67	42.48	8.18	219.1	202.7	8	128.59	244.48	33.26	...	8 900	11 000
250	62.27	60.23	9.271	273.1	254.5	8	141.29	298.45	45.55	...	8 300	9 700
300	76.11	73.75	9.525	323.9	304.8	8	150.81	355.60	71.36	...	7 600	8 300

[A] Drift pin dimensions (see Table 18)

TABLE 8 Basic Threading Data for Water-Well Reamed and Drifted Pipe (Inch-Pound Units)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Pipe			Threads[A]						Coupling			
NPS Designator	Outside Diameter, in.	Number per Inch	Length, End of Pipe to Hand-tight Plane, in.	Effective Length, in.	Total Length, End of Pipe to Vanish Point, in.	Pitch Diameter at Hand-tight Plane, in.	Outside Diameter, in.	Length, in.	Diameter of Recess, in.	Depth of Recess, in.	Length, Face of Coupling to Hand-tight Plane, in.	Width of Bearing Face, in.	Hand-tight Standoff, Threads, in.
	D[B]		L_1[B]	L_2[B]	L_4[B]	E_1[B]	W[B]	NL[B]	Q[B]	q[B]	M[B]	b[B]	A[B]
1	1.315	11½	0.4811	0.6828	0.9845	1.24369	1.576	2¾	1.378	0.1875	0.5034	1/16	0
1¼	1.660	11½	0.5051	0.7068	1.0085	1.58869	1.900	2¾	1.723	0.1875	0.5034	1/16	0
1½	1.900	11½	0.5218	0.7235	1.0252	1.82869	2.200	2¾	1.963	0.1875	0.5034	3/32	0
2	2.375	11½	0.7012	0.9884	1.2901	2.29835	2.750	3⅜	2.469	0.1875	0.5889	3/32	0
2½	2.875	8	0.9342	1.1375	1.5712	2.77792	3.250	3 15/16	2.969	0.1875	0.6370	3/32	0
3	3.500	8	0.9967	1.2000	1.6337	3.40292	4.000	4 1/16	3.594	0.1875	0.6370	⅛	0
3½	4.000	8	1.0467	1.2500	1.6837	3.90292	4.625	4 3/16	4.094	0.1875	0.6370	3/16	0
4	4.500	8	1.0967	1.3000	1.7337	4.40292	5.200	4 5/16	4.594	0.1875	0.6370	¼	0
5	5.563	8	1.2030	1.4063	1.8400	5.46592	6.296	4½	5.657	0.1875	0.6370	¼	0
6	6.625	8	1.3092	1.5125	1.9462	6.52792	7.390	4 11/16	6.719	0.1875	0.6370	¼	0
8	8.625	8	1.5092	1.7125	2.1462	8.52792	9.625	4 11/16	8.719	0.1875	0.6370	¼	0
10	10.750	8	1.7217	1.9250	2.3587	10.65292	11.750	5 9/16	10.844	0.1875	0.6370	⅜	0
12	12.750	8	1.9217	2.1250	2.5587	12.65292	14.000	5 15/16	12.844	0.1875	0.6370	⅜	0

[A] Taper of threads is ¾ in./ft on diameter for all sizes.
[B] See Fig. 2

on one length of pipe from each lot of 500 lengths, or fraction thereof, of each size. A length is defined as the length as ordered, except that in the case of orders for lengths shorter than single random, the term lot shall apply to the lengths as rolled, prior to cutting to the required short lengths.

14.2 Each length of pipe shall be subjected to the hydrostatic test as indicated for the type, size, and grade as shown in Tables 4-15. The hydrostatic pressure shall be maintained for not less than 5 s for all sizes of seamless and electric-resistance-welded pipe.

15. Retests

15.1 If the results of the tension tests of any lot do not conform to the requirements of Table 1, the lot shall be rejected, or retests shall be made on additional pipe of double

TABLE 9 Basic Threading Data for Water-Well Reamed and Drifted Pipe (SI Units)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pipe		Threads[A]						Coupling					
DN Desig-nator	Outside Diameter, mm	Number per 25.4 mm	Length, End of Pipe to Hand-tight Plane, mm	Effective Length, mm	Total Length, End of Pipe to Vanish Point, mm	Pitch Diameter at Hand-tight Plane, mm	Outside Diameter, mm	Length, mm	Diameter of Recess, mm	Depth of Recess, mm	Length, Face of Coupling to Hand-tight Plane, mm	Width of Bearing Face, mm	Hand-tight Standoff, Threads, mm
	D[B]		L_1[B]	L_2[B]	L_4[B]	E_1[B]	W[B]	NL[B]	Q[B]	q[B]	M[B]	b[B]	A[B]
25	33.4	11 ½	12.22	17.34	25.01	31.59	40.03	69.85	35.00	4.76	12.79	1.59	0
32	42.2	11 ½	12.83	17.95	25.62	40.35	48.26	69.85	43.76	4.76	12.79	1.59	0
40	48.3	11 ½	13.25	18.38	26.04	46.45	55.88	69.85	49.86	4.76	12.79	2.38	0
50	60.3	11 ½	17.81	25.11	32.77	58.38	69.85	85.73	62.71	4.76	14.96	2.38	0
65	73.0	8	23.73	28.89	39.91	70.56	82.55	100.01	75.41	4.76	16.18	2.38	0
80	88.9	8	25.32	30.48	41.50	86.43	101.60	103.19	91.29	4.76	16.18	3.18	0
90	101.6	8	26.59	31.75	42.77	99.13	117.48	106.36	103.99	4.76	16.18	4.76	0
100	114.3	8	27.86	33.02	44.04	111.83	132.08	109.54	116.69	4.76	16.18	6.35	0
125	141.3	8	30.56	35.72	46.74	138.83	159.92	114.30	143.69	4.76	16.18	6.35	0
150	168.3	8	33.25	38.42	49.43	165.81	187.71	119.06	170.66	4.76	16.18	6.35	0
200	219.1	8	38.33	43.50	54.51	216.61	244.48	119.06	221.46	4.76	16.18	6.35	0
250	273.1	8	43.73	48.90	59.91	270.58	298.45	141.29	275.44	4.76	16.18	9.53	0
300	323.9	8	48.81	53.98	64.99	321.38	355.60	150.81	326.24	4.76	16.18	9.53	0

[A] Taper of threads is 19 mm/305 mm on diameter for all sizes.
[B] See Fig. 2

TABLE 10 Dimensions,[A] Weights,[A] and Test Pressures for Driven Well Pipe (Inch-Pound Units)

NPS Designator	Weight per Foot, lb/ft		Wall Thickness, in.	Diameters, in.		No. of Threads per Inch	Coupling		Test Pressures, psi	
	Nominal Threads and Couplings	Calculated Plain Ends		Outside	Inside[A]		Calculated Weight, lb	Butt Welded	Grade A	Grade B
1	1.68	1.68	0.133	1.315	1.049	11½	0.40	700	700	700
1¼	2.28	2.27	0.140	1.660	1.380	11½	0.48	1000	1000	1100
1½	2.73	2.72	0.145	1.900	1.610	11½	0.67	1000	1000	1100
2	3.68	3.65	0.154	2.375	2.067	11½	1.05	1000	2300	2500

[A] Nominal T & C weights shown are based on the standard pipe coupling. For pipe weights with reamed and drifted coupling applied, see Table 8 of this specification. For weights with the line pipe coupling applied refer to API Standard 5L.

TABLE 11 Dimensions,[A] Weights,[A] and Test Pressures for Driven Well Pipe (SI Units)

DN Designator	Weight per Foot, kg/m		Wall Thickness, mm	Diameters, mm		No. of Threads per 25.4 mm	Coupling		Test Pressures, kPa	
	Nominal Threads and Couplings	Calculated Plain Ends		Outside	Inside[A]		Calculated Weight, kg	Butt Welded	Grade A	Grade B
25	2.50	2.50	3.38	33.40	26.64	11 ½	0.60	4800	4 800	4 800
32	3.39	3.38	3.56	42.16	35.05	11 ½	0.71	6900	6 900	7 600
40	4.06	4.05	3.68	48.26	40.89	11 ½	1.00	6900	6 900	7 600
50	5.48	5.43	3.91	60.33	52.50	11 ½	1.56	6900	15 900	17 200

[A] Nominal T & C weights shown are based on the standard pipe coupling. For pipe weights with reamed and drifted coupling applied, see Table 9 of this specification. For weights with the line pipe coupling applied refer to API Standard 5L.

the original number from the same lot, each of which shall conform to the requirements specified.

16. Test Methods

16.1 The tension tests required shall conform to those described in the latest issue of Test Methods and Definitions A 370.

16.1.1 The longitudinal tension test specimen shall be taken from the end of the pipe and for welded pipe the specimen may be taken from the skelp or strip, at a point approximately 90° from the weld and shall not be flattened between gage marks. The sides of each specimen shall be parallel between gage marks.

TABLE 12 Basic Threading Data^A for Driven Well Pipe (Inch-Pound Units)

1	2	3	4	5	6	7	8	9	10
Pipe			Threads				Joint Make-up		
NPS Designator	Outside Diameter, in.	Number per Inch	Length, End of Pipe to Hand-tight Plane, in.	Effective Length, in.	Total Length, End of Pipe to Vanish Point, in.	Pitch Diameter at Handtight Plane, in.	Length, Face of Coupling to Handtight Plane, in.	Width of Bearing Face, in.	Handtight Standoff, Threads, in.
	D^B		L_1^B	L_2^B	L_4^B	E_1^B	M^B	b^B	A^B
1	1.315	11½	0.400	0.6828	0.9845	1.23863	0.1304	approximately ⅓	5.22
1¼	1.660	11½	0.420	0.7068	1.0085	1.58338	0.1304	thickness of	5.27
1½	1.900	11½	0.420	0.7235	1.0252	1.82234	0.1304	coupling	5.46
2	2.375	11½	0.436	0.7565	1.0582	2.29627	0.1304		5.66

^A Based on standard-weight pipe with standard coupling. For basic threading data of reamed and drifted coupling see Table 10 of this specification. For line pipe coupling refer to API Standard 5L.
^B See Fig. 3.

TABLE 13 Basic Threading Data^A for Driven Well Pipe (SI Units)

1	2	3	4	5	6	7	8	9	10
Pipe			Threads				Joint Make-up		
DN Designator	Outside Diameter, mm	Number per 25.4 mm	Length, End of Pipe to Hand-tight Plane, mm	Effective Length, mm	Total Length, End of Pipe to Vanish Point, mm	Pitch Diameter at Handtight Plane, mm	Length, Face of Coupling to Handtight Plane, mm	Width of Bearing Face, in.	Handtight Standoff, Threads, mm
	D^B		L_1^B	L_2^B	L_4^B	E_1^B	M^B	b^B	A^B
25	33.40	11 ½	10.16	17.34	25.01	31.46	3.31	approximately	132.59
32	42.16	11 ½	10.67	17.95	25.62	40.22	3.31	⅓ thickness	133.86
40	48.26	11 ½	10.67	18.38	26.04	46.29	3.31	of coupling	138.68
50	60.33	11 ½	11.07	19.22	26.88	58.33	3.31		143.76

^A Based on standard-weight pipe with standard coupling. For basic threading data of reamed and drifted coupling see Table 11 of this specification. For line pipe coupling refer to API Standard 5L.
^B See Fig. 3.

TABLE 14 Dimensions, Weights, and Test Pressures for Water-Well Casing (Inch-Pound Units)

Size, Outside Diameter, in.	Weight per Foot, lb/ft		Wall Thickness, in.	Diameters, in.		No. of Threads per Inch	Couplings			Test Pressures, psi
	Threads and Couplings	Plain Ends		Outside	Inside		Length, in.	Outside Diameter, in.	Calculated Weight, lb	
3.500	4.60	4.51	0.125	3.500	3.250	14	3⅛	4.000	2.86	1100
4.000	5.65	5.53	0.134	4.000	3.732	14	3⅛	4.500	3.24	1000
4.500	6.75	6.61	0.142	4.500	4.216	14	3⅝	5.000	4.26	950
5.500	9.00	8.79	0.154	5.500	5.192	14	4⅛	6.050	6.38	850
6.000	10.50	10.22	0.164	6.000	5.672	14	4⅛	6.625	7.84	850
6.625	13.00	12.72	0.185	6.625	6.255	11½	4⅝	7.390	11.88	850
8.625	17.80	16.90	0.188	8.625	8.249	11½	5¼	9.625	22.92	650

16.1.2 Transverse weld test specimen from electric-welded pipe shall be taken with the weld at the center of the specimen. All transverse test specimens shall be 1½ in. [38 mm] wide in the gage length and shall represent the full wall thickness of the pipe from which the specimen was cut.

16.1.3 All specimens shall be tested at room temperature.

17. Hydrostatic Test

17.1 Each length of pipe shall be tested at the mill to the hydrostatic pressures as prescribed for each type of pipe in Table 2, Table 3, Table 6, Table 7, Table 10, Table 11, Table 14, and Table 15 . The hydrostatic test may be applied at the discretion of the manufacturer on pipe with plain ends, with threads only, or with threads and coupling.

18. Inspection

18.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment unless otherwise

TABLE 15 Dimensions, Weights, and Test Pressures for Water-Well Casing (SI Units)

Size, Outside Diameter, mm	Weight per Foot, kg/m		Wall Thickness, mm	Diameters, mm		No. of Threads per 25.4 mm	Couplings			Test Pressures, kPa
	Threads and Couplings	Plain Ends		Outside	Inside		Length, mm	Outside Diameter, mm	Calculated Weight, kg/m	
88.9	6.84	6.71	3.18	88.9	82.6	14	79.38	101.60	4.26	7600
101.6	8.41	8.23	3.40	101.6	94.8	14	79.38	114.30	4.82	6900
114.3	10.04	9.84	3.61	114.3	107.1	14	92.08	127.00	6.34	6600
139.7	13.39	13.08	3.91	139.7	131.9	14	104.78	153.67	9.49	5900
152.4	15.62	15.21	4.17	152.4	144.1	14	104.78	168.28	11.67	5900
168.3	19.34	18.93	4.70	168.3	158.9	11 ½	117.48	187.71	17.68	5900
219.1	26.49	25.15	4.78	219.1	209.5	11 ½	133.35	244.48	34.10	4500

TABLE 16 Basic Threading Data for Water-Well Casing (Inch-Pound Units)

1	2	3	4	5	6	7	8	9	10	11	12	13
			Threads, in.[A]						Coupling, in.			
Size, Outside Diameter, in.	Number per Inch	Length, End of Pipe to Hand-tight Plane, in.	Effective Length, in.	Total Length, End of Pipe to Vanish Point, in.	Pitch Diameter at Hand-tight Plane, in.	Outside Diameter, in.	Length, in.	Diameter of Recess, in.	Depth of Recess, in.	Length, Face of Coupling to Hand-tight Plane, in.	Width of Bearing Face, in.	Hand-tight Standoff, in.
3½	14	0.5241	1.0455	1.3071	3.4296	4.000	3⅛	3 19/32	¼	0.426	5/32	5
4	14	0.5741	1.0955	1.3571	3.9296	4.500	3⅛	4 3/32	¼	0.426	5/32	5
4½	14	0.6241	1.1455	1.4071	4.4296	5.000	3⅝	4 19/32	¼	0.426	5/32	5
5½	14	0.7241	1.2455	1.5071	5.4296	6.050	4⅛	5 19/32	¼	0.426	5/32	5
6	14	0.7741	1.2955	1.5571	5.9296	6.625	4⅛	6 3/32	¼	0.426	5/32	5
6⅝	11½	0.9123	1.3784	1.6973	6.5445	7.390	4⅝	6 23/32	¼	0.437	3/16	4
8⅝	11½	1.1123	1.5784	1.8973	8.5445	9.625	5¼	6 23/32	¼	0.437	3/16	4

[A] Taper of threads is ⅜ in./ft on diameter for all sizes.

TABLE 17 Basic Threading Data for Water-Well Casing (SI Units)

1	2	3	4	5	6	7	8	9	10	11	12	13
			Threads[A]						Coupling			
Size, Outside Diameter, mm	Number per 25.4 mm	Length, End of Pipe to Hand-tight Plane, mm	Effective Length, mm	Total Length, End of Pipe to Vanish Point, mm	Pitch Diameter at Hand-tight Plane, mm	Outside Diameter, mm	Length, mm	Diameter of Recess, mm	Depth of Recess, mm	Length, Face of Coupling to Hand-tight Plane, mm	Width of Bearing Face, mm	Hand-tight Standoff, mm
88.90	14	13.31	26.56	33.20	87.11	101.60	79.38	91.28	6.35	10.82	3.97	5
101.60	14	14.58	27.83	34.47	99.81	114.30	79.38	103.98	6.35	10.82	3.97	5
114.30	14	15.85	29.10	35.74	112.51	127.00	92.08	116.68	6.35	10.82	3.97	5
139.70	14	18.39	31.64	38.28	137.91	153.67	104.78	142.08	6.35	10.82	3.97	5
152.40	14	19.66	32.91	39.55	150.61	168.28	104.78	154.78	6.35	10.82	3.97	5
168.28	11 ½	23.17	35.01	43.11	166.23	187.71	117.48	170.66	6.35	11.10	4.76	4
219.08	11 ½	28.25	40.09	48.19	217.03	244.48	133.35	170.66	6.35	11.10	4.76	4

[A] Taper of threads is 9.53 mm/305 mm on diameter for all sizes.

specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

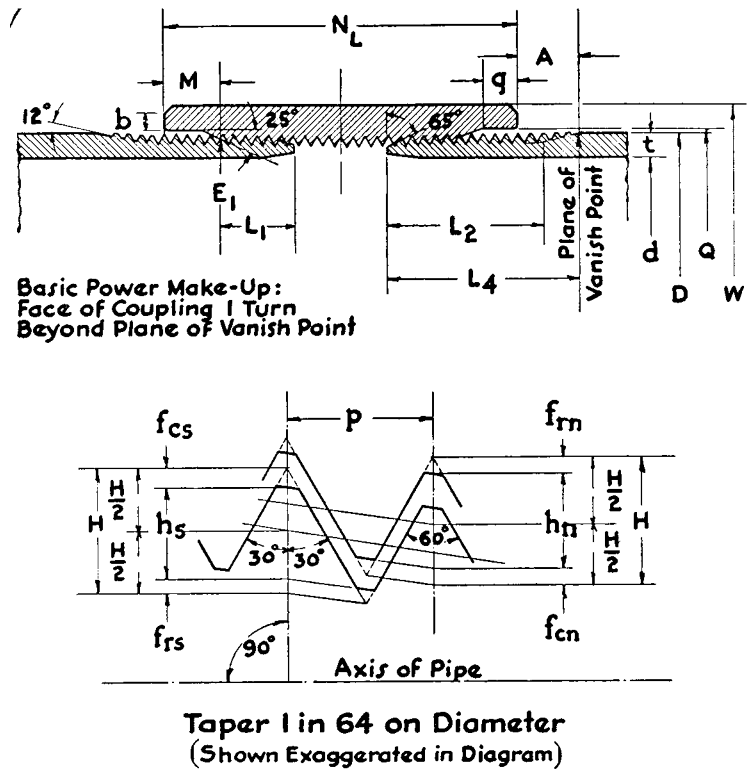
19. Rejection

19.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

19.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the

TABLE 18 Drift Pin Dimensions

NPS Designator [DN]	Length of Pin, in. [mm]	Diameter of Pin, in. [mm], Smaller Than Nominal Inside Diameter of Pipe
To 6 [DN 150], incl	12 [305]	3/32 [2.38]
8 [DN 200], 10 [DN 250], and 12 [DN 300]	12 [305]	⅛ [3.18]



Thread Height Dimensions, in.

Thread Element	in. 8 Threads per Inch p = 0.125	mm 8 Threads per 25.4 mm p = 3.175
$H = 0.866p$	0.1082	2.748
$h_s = h_n = 0.760p$	0.0950	2.413
$f_{rs} = f_{rn} = 0.033p$	0.0041	0.1041
$f_{cs} = f_{cn} = 0.073p$	0.0091	0.2311

FIG. 1 Basic Threading Data for Drive Pipe (Handling-Tight Assembly) (See Tables 4 and 5)

forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

20. Certification

20.1 The producer or supplier shall, upon request, furnish to the purchaser a certification of inspection stating that the material has been manufactured, sampled, tested, and inspected in accordance with this specification (including the year date designation) and has been found to meet the requirements.

21. Product Marking

21.1 Each length of pipe shall be legibly marked by rolling, stamping, or stenciling to show: the name or brand of the manufacturer, type number, the kind of pipe (butt-welded, electric-resistance-welded, or seamless), grade, nominal or outside diameter size, wall thickness, the specification number and the length. Length shall be marked in feet and tenths of a foot or metres to two decimal places, depending on the units to which the material was ordered or other marking subject to agreement.

21.2 Marking shall begin approximately 12 in. [305 mm] from the coupling of each length.

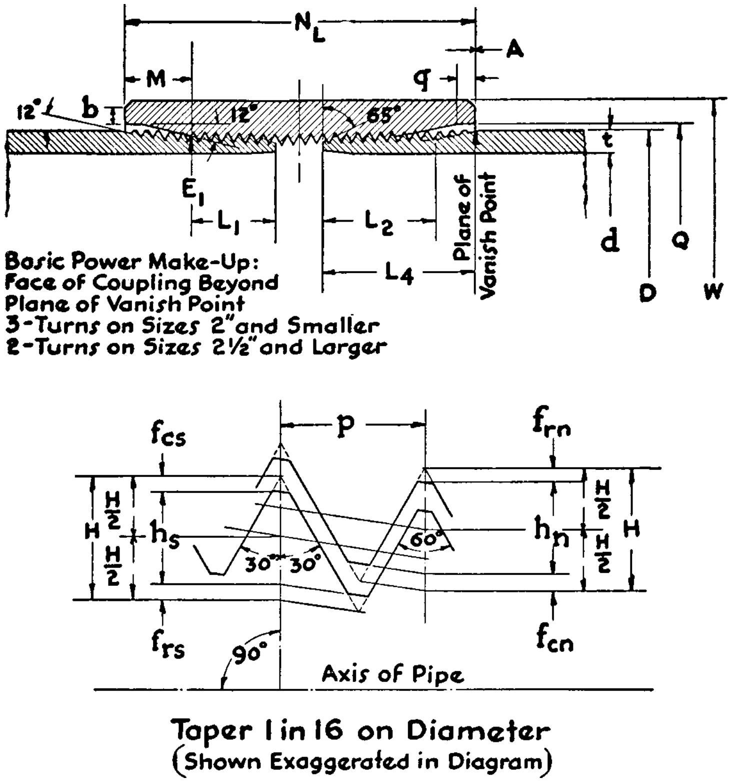
21.3 Type II pipe NPS 1½ [DN 40] and under and for all sizes of Type III pipe, the required marking as specified in 21.1 may be applied to a tag securely attached to the bundle or bale prepared for shipment.

NOTE 2—When pipe sections are cut into shorter lengths by a subsequent processor for resale as material, the processor shall transfer complete identifying information to each unmarked cut length, or to metal tags securely attached to bundles of unmarked small diameter pipe. The same material designation shall be included with the information transferred, and the processor's name, trademark, or brand shall be added.

21.4 *Bar Coding*—In addition to the requirements in 21.1, 21.2, and 21.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

22. Packaging

22.1 All types and sizes of water well pipe may be shipped loose except that NPS 1½ [DN 40] and smaller sizes of Type



Thread Height Dimensions, in.

Thread Element	in. 11½ Threads per Inch p = 0.0870	mm 11½ Threads per 25.4 mm p = 2.209	in. 8 Threads per Inch p = 0.125	mm 8 Threads per 25.4 mm p = 3.175
$H = 0.866p$	0.0753	1.913	0.1082	2.748
$h_s = h_n = 0.760p$	0.0661	1.679	0.0950	2.413
$f_{rs} = f_{rn} = 0.033p$	0.0029	0.074	0.0041	0.104
$f_{cs} = f_{cn} = 0.073p$	0.0063	0.160	0.0091	0.231

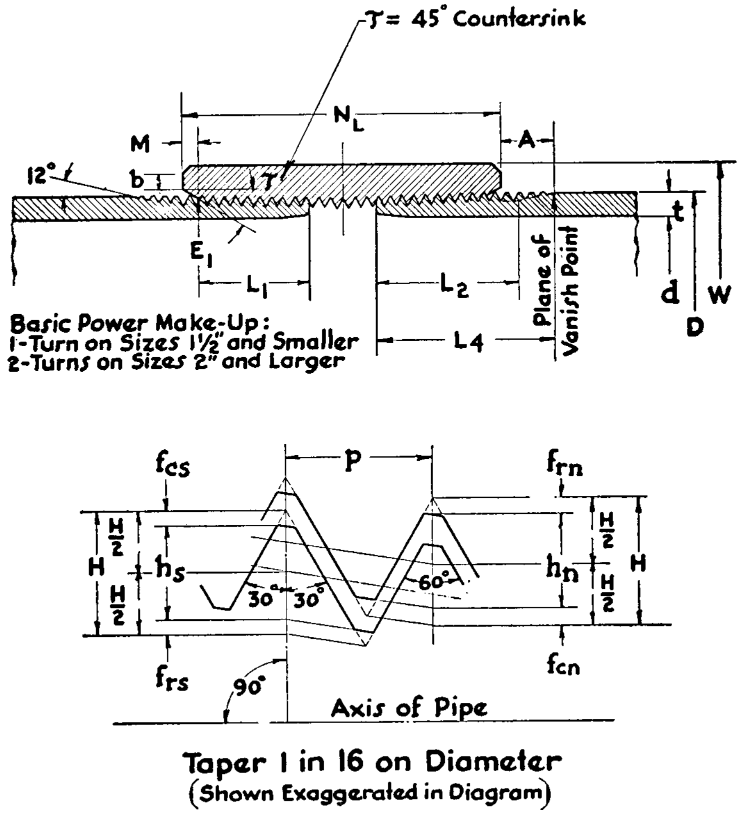
FIG. 2 Basic Threading Data for Water-Well Reamed and Drifted Pipe (Handling-Tight Assembly) (See Tables 8 and 9)

II pipe and all sizes of Type III pipe shall be packaged in bundles or bales of convenient size for handling.

22.2 If special packaging is required for any pipe size, such requirements shall be negotiated and the required practice shall be indicated on the purchase order.

23. Keywords

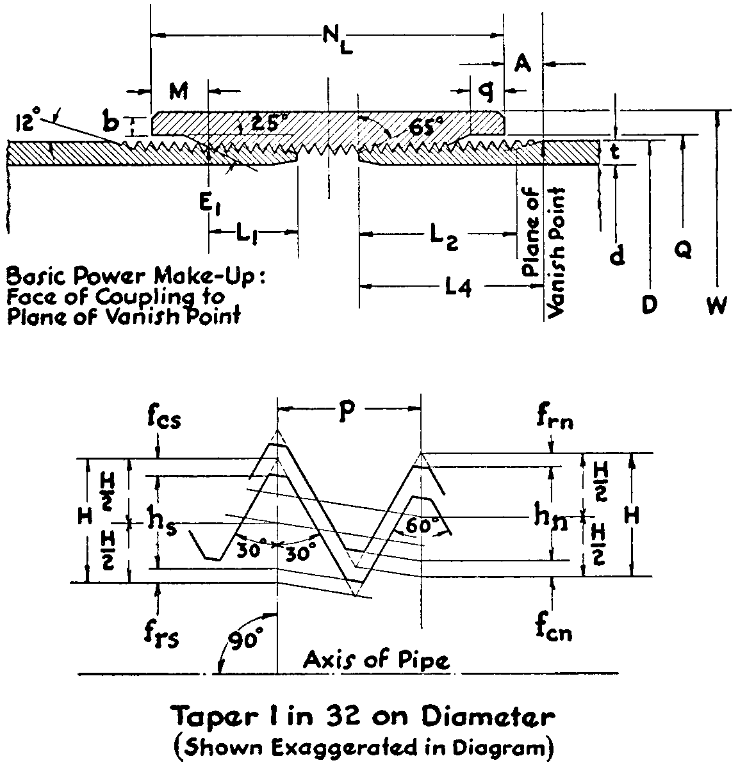
23.1 carbon steel pipe; seamless steel pipe; steel pipe; water well pipe; welded steel pipe



Thread Height Dimensions, in.

	in.	mm
Thread Element	11½ Threads per Inch p = 0.0870	11½ Threads per 25.4 mm p =2.209
H = 0.866p	0.0753	1.913
h_s= h_n= 0.760p	0.0661	1.679
f_{rs}= f_{rn}= 0.033p	0.0029	0.074
f_{cs}= f_{cn}= 0.073p	0.0063	0.160

FIG. 3 Basic Threading Data for Driven Well Pipe (Handling-Tight Assembly) (See Tables 12 and 13)



Thread Height Dimensions, in.

	in.	mm	in.	mm
Thread Element	14 Threads per Inch p = 0.0714	14 Threads per 25.4 mm p = 1.814	11½ Threads per Inch p = 0.0870	11½ Threads per 25.4 mm p = 2.209
H = 0.866p	0.0619	1.572	0.0753	1.913
h_s= h_n= 0.760p	0.0543	1.379	0.0661	1.679
f_{rs}= f_{rn}= 0.033p	0.0024	0.061	0.0029	0.074
f_{cs}= f_{cn}= 0.073p	0.0052	0.132	0.0063	0.160

FIG. 4 Basic Threading Data for Water-Well Casing (Handling-Tight Assembly) (See Tables 16 and 17)

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 589 – 96(2001), that may impact the use of this specification. (Approved March 1, 2006)

(*1*) Added metric dimensions in the text.
(*2*) Added metric tables for all "inch-pound" tables.
(*3*) Deleted old Table 2 and renumbered subsequent tables and references.

Designation: A 587 – 96 (Reapproved 2005)

Standard Specification for Electric-Resistance-Welded Low-Carbon Steel Pipe for the Chemical Industry[1]

This standard is issued under the fixed designation A 587; 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 electric-resistance-welded low-carbon steel pipe intended for use as process lines.

1.2 Pipe ordered under this specification shall be suitable for severe forming operations involving flanging in all sizes and bending to close radii up to and including NPS 4.

1.3 This specification covers NPS ½ through 10, plus additional sizes. The corresponding outside diameters and wall thicknesses for NPS ½ through 10 are listed in Table 1, as are the dimensions for the additional sizes.

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."

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 The following precautionary caveat pertains only to the test method portion, Sections 6, 12, and 13, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing

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

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

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 or number of pieces),

3.1.2 Name of material (electric-resistance-welded steel pipe),

3.1.3 Size (NPS or outside diameter and wall thickness),

3.1.4 Length (definite cut length or random),

3.1.5 Test report required (see 14.2),

3.1.6 Specification number, and

3.1.7 Special requirements.

4. Materials and Manufacture

4.1 *Process*—The steel shall be aluminum killed steel made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

4.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Oct. 1, 2005. Published November 2005. Originally approved in 1968. Last previous edition approved in 2001 as A 587 – 96 (2001).

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-587 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.

TABLE 1 Tolerance for Outside Diameter and Wall Thickness

NPS Designator	Outside Diameter	Wall Thickness					
		Min	Nom	Max	Min	Nom	Max
				Inches			
—	0.8125 ± 0.004	0.095	0.103	0.111	0.129	0.140	0.151
½	0.840 ± 0.006	0.095	0.103	0.111	0.125	0.140	0.151
¾	1.050 ±0.006	0.099	0.108	0.117	0.135	0.147	0.159
—	1.0625 ± 0.006	0.099	0.108	0.117	0.135	0.147	0.159
—	1.3125 ± 0.006	0.116	0.126	0.136	0.157	0.171	0.185
1	1.315 ± 0.006	0.116	0.126	0.136	0.157	0.171	0.185
1¼	1.660 ± 0.007	0.121	0.132	0.143	0.167	0.182	0.197
—	1.875 ± 0.008	0.127	0.138	0.149	0.175	0.190	0.205
1½	1.900 ± 0.008	0.127	0.158	0.149	0.175	0.190	0.205
2	2.375 ± 0.010	0.135	0.147	0.159	0.191	0.208	0.225
3	3.500 ± 0.015	0.189	0.206	0.223	0.262	0.286	0.310
4	4.500 ± 0.017	0.207	0.226	0.245	0.295	0.322	0.349
6	6.625 ± .030	0.245	0.267	0.289	0.378	0.412	0.446
8	8.625 ± .040	0.282	0.308	0.334	0.438	0.478	0.518
10	10.750 ± .050	0.319	0.348	0.377	0.520	0.567	0.614
				Millimetres			
—	20.64 ± 0.10	2.41	2.62	2.82	3.28	3.56	3.84
½	21.30 ± 0.15	2.41	2.62	2.82	3.28	3.56	3.84
¾	26.70 ± 0.15	2.51	2.74	2.97	3.43	3.73	4.04
—	26.99 ± 0.15	2.51	2.74	2.97	3.43	3.73	4.04
—	33.34 ± 0.15	2.95	3.20	3.45	3.99	4.34	4.70
1	33.40 ± 0.15	2.95	3.20	3.45	3.99	4.34	4.70
1¼	42.16 ± 0.18	3.07	3.35	3.63	4.24	4.62	5.00
—	47.63 ± 0.20	3.22	3.51	3.78	4.45	4.83	5.21
1½	48.30 ± 0.020	3.22	3.51	3.78	4.45	4.83	5.21
2	60.33 ± 0.25	3.43	3.73	4.04	4.85	5.28	5.72
3	88.90 ± 0.38	4.80	5.23	5.66	6.66	7.26	7.87
4	114.30 ± 0.43	5.26	5.74	6.22	7.49	8.18	8.87
6	168.28 ± 0.76	6.22	9.32	7.34	9.60	10.47	11.33
8	219.08 ± 1.02	7.16	7.82	8.48	11.13	12.14	13.16
10	273.05 ± 1.27	8.10	8.84	9.58	13.21	14.40	15.60

4.3 *Manufacture*—The pipe shall be made by electric resistance welding.

4.4 *Heat Treatment*—Pipe furnished in the as-welded condition shall be normalized at a temperature above the upper critical temperature. Cold-drawn pipe shall be normalized after the final cold-draw pass.

5. Chemical Composition

5.1 *Heat Analysis*—An analysis of each heat of steel shall be made to determine the percentages of the elements specified. The chemical composition thus determined shall conform to the requirements specified in Table 2 and the chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

5.2 *Product Analysis*—When requested on the purchase order, a product analysis shall be made by the supplier from one pipe or coil of steel per heat. The chemical composition thus determined shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Table 2.

TABLE 2 Chemical Composition Requirements

Element	Composition, %
Carbon, max	0.15
Manganese	0.27–0.63
Phosphorus, max	0.035
Sulfur, max	0.035
Aluminum	0.02–0.100

5.3 *Retests*—If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or pipe shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise, all remaining material in the heat shall be rejected or, at the option of the producer, each length of flat-rolled stock or pipe may be individually tested for acceptance. Lengths of flat-rolled stock or pipe which do not meet the requirements of the specification shall be rejected.

5.4 Supplying an alloy grade of steel that specifically requires the addition of any element other than those listed in Table 2 is not permitted.

6. Mechanical Requirements

6.1 *Tensile Properties*:

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

6.1.2 The yield strength shall be determined by the drop of the beam, by the halt in the gauge of the testing machine, by the use of dividers, or by other approved methods. When a definite yield point is not exhibited, the yield strength corresponding to a permanent offset of 0.2 % of the gauge length of the

TABLE 3 Tensile Requirements

Tensile strength, min, psi (MPa)	48 000 (331)
Yield strength, min, psi (MPa)	30 000 (207)
Elongation in 2 in. or 50 mm, min, %	40

specimen, or to a total extension of 0.5 % of the gauge length under load, shall be determined.

6.1.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than ¾ in. (19 mm) from the center of the gauge length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

6.2 *Flattening Test*:

6.2.1 A section of pipe not less than 4 in. (102 mm) in length shall be flattened cold between parallel plates in two steps. The weld shall be placed 90° from the direction of the applied force. During the first step, which is a test for ductility, no cracks or breaks, except as provided for in 6.2.5, shall occur on the inside or outside surfaces until the distance between the plates is less than the value of H, calculated by the following equation:

$$H = [(1 + e)t] / [e + t/D] \tag{1}$$

where:

H = distance between flattening plates, in.,
t = specified wall thickness of the pipe, in.,
D = specified outside diameter of the pipe, in., and
e = deformation per unit length (0.09 for low-carbon steel).

6.2.2 During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

6.2.3 Surface imperfections in the test specimens before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

6.2.4 Superficial ruptures resulting from surface imperfections shall not be cause for rejection.

6.2.5 When low *D*-to- *t* ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the *D*-to-*t* ratio is less than 10.

6.3 *Reverse Flattening Test*—A section 4 in. (102 mm) in length of pipe in sizes down to and including 13⁄16 in. (20.6 mm) in outside diameter shall be split longitudinally 90° on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There shall be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

6.4 *Flange Test*—A section of pipe not less than 4 in. (102 mm) in length shall be capable of having a flange turned over at a right angle to the body of the pipe without cracking or showing flaws. This flange, as measured from the outside of the pipe, shall be not less than ⅛ in. (3.2 mm) nor more than ½ in. (12.7 mm). Within these limits, the width of the flange shall be not less than the percentages specified in Table 4.

7. Dimensions and Permissible Variations

7.1 *Permissible Variations in Outside Diameter and Wall Thickness*—The outside diameter and wall thickness variations shall not exceed the limits prescribed in Table 1.

TABLE 4 Flange Requirements

Outside Diameter of Pipe, in.	Width of Flange, % of OD
Over ¾ to 2½ , incl	15
Over 2½ to 3¾ , incl	12½
Over 3¾ to 4½ , incl	10
Over 4½ to 6⅝ , incl	7½
Over 6⅝	5

7.2 *Permissible Variations in Straightness*—Each pipe shall be straight within 0.030 in. (0.76 mm) maximum deflection in any 3 ft (0.91 m) length to 8 NPS. For 8 NPS and above, pipe shall be straight within 0.060 in. (1.52 mm) maximum deflection in any 3 ft (0.91 m) length. Galvanized pipe shall be reasonably straight.

7.3 *Lengths*:

7.3.1 Pipe may be ordered in definite cut lengths or in random lengths as provided herein.

7.3.2 When ordered in definite cut lengths, the variation in length shall not exceed the amounts prescribed in Table 5.

7.3.3 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft (4.9 to 6.7 m) with 5 % 12 to 16 ft (3.7 to 4.9 m), or in double random lengths with a minimum average of 35 ft (10.7 m) and a minimum length of 22 ft (6.7 m) with 5 % 16 to 22 ft (4.9 to 6.7 m).

8. Workmanship, Finish, and Appearance

8.1 The finished pipe shall be free of injurious defects and shall have a workman-like finish. Minor defects may be removed by grinding, provided the wall thickness is not reduced to less than the minimum thickness permitted for the ordered nominal wall thickness.

8.2 The pipe shall have smooth ends free of burrs and free of scale except that the pipe may have a superficial "blue" oxide film on the surfaces.

8.3 For NPS ½ to 1½ inclusive, the inside diameter welding flash shall be removed so that the remaining flash does not exceed 0.006 in. (0.15 mm). For NPS over 1½ , the remaining inside diameter welding flash shall not exceed 0.010 in. (0.25 mm).

8.4 For all nominal sizes, the outside diameter welding flash shall be removed flush with the outside diameter contour.

8.5 Undercut flash must be smoothly blended into the pipe wall.

8.6 The intent of the flash conditions as prescribed in 8.3, 8.4, and 8.5 is to obtain a surface contour suitable for flanging.

9. Number of Tests

9.1 Two tensile tests as specified in 6.1 shall be made from each heat.

TABLE 5 Permissible Variations in Length[A]

Outside Diameter, in.	Cut Length, in. (mm)	
	Over	Under
Under 2	⅛ (3.2)	0
2 and over	3⁄16 (4.8)	0

[A] These permissible variations in length apply to pipe before bending. They apply to cut lengths up to and including 24 ft (7.3 m). For lengths over 24 ft, an additional over-tolerance of ⅛ in. for each 10 ft (3.0 m) or fraction thereof shall be permissible, up to a maximum of ½ in. (12.7 mm).

9.2 The flattening test as specified in 6.2 shall be made on two lengths of pipe from each lot of 250 lengths or fraction thereof.

9.3 The reverse flattening test specified in 6.3 shall be made on 1 length of pipe from each lot of 250 lengths or fraction thereof.

9.4 The flange test as specified in 6.4 shall be made on specimens from 2 lengths of pipe from each lot of 250 lengths or fraction thereof.

10. Retests

10.1 If the results of the mechanical tests of any heat or lot do not conform to the requirements specified, retests may be made on additional pipe of double the original number from the same heat or lot, each of which shall conform to the requirements specified.

11. Retreatment

11.1 If a heat or lot fails to conform to the test requirements, that heat or lot may be reheat treated and resubmitted for tests. Not more than one reheat treatment shall be permitted.

12. Test Specimens and Methods of Testing

12.1 The test specimens and the tests required by this specification shall conform to those described in Test Methods and Definitions A 370.

12.2 Test specimens shall be taken from the ends of finished pipe prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free from burrs and flaws.

12.3 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

13. Nondestructive Test

13.1 The nondestructive test shall be made instead of the hydrostatic test.

13.1.1 The test shall provide a 360° inspection for sizes up to and including 3½ in. (88.9 mm) outside diameter.

13.1.2 For pipe larger than 3½ in. (88.9 mm) outside diameter, nondestructive inspection of the weld and heat affected zone is required.

13.2 Each pipe shall be tested with a nondestructive test in accordance with Practices E 213, E 273, E 309, or E 570. Except as provided in 13.6.2, it is the intent of this test to reject pipe with imperfections that produce test signals equal to or greater than that of the calibration standard. In order to accommodate the various types of nondestructive testing equipment and techniques in use, and manufacturing practices employed, any one of the following calibration standards may be used, at the option of the producer, to establish a minimum sensitivity level for rejection:

13.3 For eddy-current testing, the calibration pipe shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection. For welded pipe, they shall be placed in the weld if visible.

13.3.1 *Drilled Hole*—A hole not larger than 0.031 in. (0.79 mm) in diameter shall be drilled radially and completely through the pipe wall, taking care to avoid distortion of the pipe while drilling.

13.3.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼-in. 6.4 mm diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe, preferably in the weld area. Said notch shall have a depth not exceeding 12½ % of the specified wall thickness of the pipe or 0.004 in. (0.10 mm), whichever is greater.

13.3.3 *Longitudinal Notch*—A notch 0.031 in. (0.79 mm) or less in width shall be machined in a radial plane parallel to the pipe axis on the outside surface of the pipe, to a depth not exceeding 12½ % of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

13.4 For ultrasonic testing, the longitudinal calibration reference notches shall be at the option of the producer, any one of the three common notch shapes shown in Practices E 213 or E 273. The depth of the notch shall not exceed 12½ % of the specified wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater. For welded pipe, the notch shall be placed in the weld, if visible.

13.5 For flux leakage testing, each of the longitudinal calibration notches shall be a straight-sided notch not over 12½ % of the wall thickness in depth and not over 1.0 in. (25 mm) in length. Both outside diameter and inside diameter notches shall be placed in the tube located sufficiently apart to enable separation and identification of the signals.

13.6 Pipe producing a signal equal to or greater than the calibration defect shall be subject to rejection. The area producing the signal may be examined.

13.6.1 Test signals produced by imperfections that cannot be identified, or produced by cracks or crack-like defects shall result in rejection of the pipe subject to rework and retest.

13.6.2 Test signals produced by imperfections such as those listed below may be judged as injurious or noninjurious depending on visual observation or their severity or the type of signal they produce on the testing equipment used, or both:

13.6.2.1 Dinges,

13.6.2.2 Straightener marks,

13.6.2.3 Loose inside diameter bead and cutting chips,

13.6.2.4 Scratches,

13.6.2.5 Steel die stamps,

13.6.2.6 Chattered flash trim,

13.6.2.7 Stop marks, or

13.6.2.8 Tube reducer ripple.

13.6.3 Any imperfection of the above type exceeding 0.004 in. (0.102 mm) or 12½ % of the specified wall thickness (whichever is greater) in depth shall be considered injurious.

13.6.3.1 If the imperfection is judged as injurious, the pipe shall be rejected but may be reconditioned and retested providing the dimensional requirements are met.

13.6.3.2 If the imperfection is explored to the extent that it can be identified as noninjurious, the pipe may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness.

14. Inspection

14.1 The inspector shall have entry at all times while work on an order is being done to all parts of the manufacturer's works that concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. All tests and inspection shall be made prior to shipment.

14.2 When inspection at the place of manufacture has been waived by customer, the manufacturer shall furnish a statement that the material has been tested and has met all the requirements of this specification. A certificate or report shall be made available to customer when all the requirements of this specification have been met. When Supplementary Requirement S1 is furnished, certificates or reports furnished shall bear the notation "S-1."

15. Rejection

15.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

15.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

16. Product Marking

16.1 Each length of pipe NPS 1½ and larger shall be legibly marked by either stenciling or stenciling and light die marking. The die marking shall include the manufacturer's logo or symbol and the stenciling shall include the name or brand of the manufacturer, size, heat number, and the specification number. Such marking shall be applied starting within 8 in. (203 mm) of the end of each length.

16.2 For NPS under 1½ the markings prescribed in 16.1 may be applied to tags and securely attached to the bundle, bale, or other unit, prepared for shipment.

16.3 A tag shall be securely attached to each bundle of pipe shipped indicating the name of the manufacturer, size, wall thickness, length, and specification.

16.4 *Bar Coding*—In addition to the requirements in 16.1, 16.2, and 16.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

17. Packaging

17.1 The manufacturer, at his option, will box, crate, carton, or package in secured lifts, or bundle to ensure safe delivery. Special packaging requiring extra operations other than those normally used by the manufacturer must be specified on the order.

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements described below may be included in the purchaser's order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirements details not fully described shall be agreed upon between the purchaser and the supplier, but shall not negate any of the requirements in the body of the specification.

S1. Hydrostatic Testing

S1.1 Hydrostatic testing shall be in accordance with Specification A 530/A 530M. When this supplement is furnished the pipe shall be marked "S-1."

S2. Galvanizing

S2.1 Galvanizing shall be in accordance with Specification A 53/A 53M, except that the rate of application shall be 1.3 minimum to 1.7 maximum oz per f^2.

S3. Surface Coatings

S3.1 All surfaces shall be coated, the exterior with a hard drying lacquer, and the interior with a suitable rust inhibitor.

Designation: A 556/A 556M – 96 (Reapproved 2005)

Standard Specification for Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes[1]

This standard is issued under the fixed designation A 556/A 556M; 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 minimum-wall-thickness, seamless cold-drawn carbon steel tubes including bending into the form of U-tubes, if specified, for use in tubular feedwater heaters.

1.2 The tubing sizes covered shall be ⅝ to 1¼-in. [15.9 to 31.8-mm] outside diameter, inclusive, with minimum wall thicknesses equal to or greater than 0.045 in. [1.1 mm].

1.3 Optional supplementary requirements are provided, and when desired, shall be stated in the order.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as the 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:* [3]

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[4]

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 pieces),

3.1.2 Name of material (seamless steel tubing),

3.1.3 Dimensions (outside diameter and minimum wall thickness),

3.1.4 Length (specific or random),

3.1.5 Manufacture (cold drawn),

3.1.6 Grade (chemical composition),

3.1.7 Optional requirements,

3.1.8 *Bending Requirements*— If order specifies tubes to be bent, the design of the U-tubes shall accompany the order. Purchaser must specify if stress-relief anneal of the U-bends is required,

3.1.9 Test report required (see Certification Section of Specification A 450/A 450M),

3.1.10 Specification number, and

3.1.11 Special requirements and any supplementary requirements selected.

4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of the Specification A 450/A 450M, unless otherwise provided herein.

5. Manufacture

5.1 *Manufacture*—Tubes shall be made by the seamless process and shall be cold drawn.

5.2 *Heat Treatment*:

5.2.1 Cold-drawn tubes shall be heat treated after the final cold-draw pass at a temperature of 1200°F [640°C] or higher to ensure ductility satisfactory for rolling into tube sheets and to meet mechanical properties as specified.

5.2.2 If stress-relief anneal of the U-bends is specified, the anneal shall consist of heating the bent portion within a range of 1100 to 1200°F [585 to 640°C].

6. Chemical Composition

6.1 The steel shall conform to one of the requirements as to chemical composition as prescribed in Table 1.

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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 A01.09 on Carbon Steel Tubular Products.

Current edition approved October 1, 2005. Published November 2005. Originally approved in 1965. Last previous edition approved in 2001 as A 556/A 556M – 96 (2001).

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-556 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] Withdrawn.

TABLE 1 Chemical Requirements

Element	Composition, %		
	Grade A2	Grade B2	Grade C2
Carbon, max	0.18	0.27	0.30
Manganese	0.27–0.63	0.29–0.93	0.29–1.06
Phosphorus, max	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035
Silicon, min	...	0.10	0.10

6.2 When a grade is 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.

7. Product Analysis

7.1 When requested in the purchase order, a product analysis shall be made by the manufacturer or supplier from one tube or billet per heat.

7.2 If the original test for product analysis fails, retests of two additional tubes or billets shall be made. Both retests for the elements in question shall meet the requirements of this specification; otherwise, all remaining material in the heat or lot (Note 1) shall be rejected or, at the option of the producer, each tube may be individually tested for acceptance. Tubes that do not meet the requirements of this specification shall be rejected.

NOTE 1—For tension 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.

7.3 For referee purposes, Test Methods E 30 shall be used.

8. Mechanical Properties

8.1 *Tensile Properties*—The material shall conform to the requirements as to tensile properties prescribed in Table 2, when pulled in full section.

8.2 *Hardness Requirements*—The tubes shall not exceed the Rockwell Hardness shown in Table 3.

9. Permissible Variations in Dimensions (Fig. 1)

9.1 Permissible variations from the specified outside diameter shall not exceed ±0.004 in. [0.10 mm] for tubing under 1.0-in. [25.4-mm] outside diameter nor ±0.006 in. [0.15 mm] for tubing 1.0 in. [25.4 mm] to 1.25 in. [31.7 mm] inclusive. These tolerances do not apply to the bent portion of the U-tubes. At the bent portion of a U-tube for $R = 2 \times D$ or greater neither the major nor minor diameter of tube shall deviate from nominal by more than 10 %. If 1½ D is specified, tolerances could be greater.

TABLE 2 Tensile Requirements

	Grade A2	Grade B2	Grade C2
Tensile strength, min, ksi [MPa]	47 [320]	60 [410]	70 [480]
Yield strength, min, ksi [MPa]	26 [180]	37 [260]	40 [280]
Elongation in 2 in. or 50 mm, min, % (longitudinal)	35	30	30

TABLE 3 Hardness Requirements

Grade A2	HR B 72
Grade B2	HR B 79
Grade C2	HR B 89

9.2 Permissible variations from the specified minimum wall thickness shall not exceed +20 % or −0. The wall thickness of the tube in U-bent section shall be not less than value determined by:

$$t_f = T\,(2R)\,/\,(2R+D) \quad (1)$$

where:

t_f = wall thickness after bending, in. [mm],
T = specified minimum tube wall thickness, in. [mm],
R = centerline bend radius, in. [mm], and
D = nominal outside tube diameter, in. [mm].

9.3 In the case of U-tubes, the length of the tube legs as measured from the point of tangency of the bend and the tube leg to the end of the tube leg shall not be less than specified, but may exceed the specified values by the amount given in Table 4. The difference in lengths of the tube legs shall not be greater than ⅛ in. [3 mm] unless otherwise specified.

9.4 The end of any tube may depart from square by not more than the amount given in Table 5.

9.5 The leg spacing measured between the points of tangency of the bend to the legs shall not vary from the value (2R − specified tube OD) by more than 1⁄16 in. [1.5 mm] where R is the centerline bend radius.

9.6 The bent portion of the U-tube shall be substantially uniform in curvature and not exceed ±1⁄16 in. [±1.5 mm] of the normal centerline radius.

10. Workmanship, Finish, and Appearance

10.1 Finished tubes shall be free from scale but may have a superficial oxide film on the surfaces. A light oxide scale on the outside and inside surfaces of U-bend shall be allowed for tubes which have been heat treated.

10.2 Finished tubes shall be reasonably straight and have smooth ends free from burrs. Tubes shall have a workmanlike finish and shall be free of surface imperfections that cannot be removed within the allowable wall tolerances. Removal of surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be required provided they are within the allowable wall tolerances.

10.3 Finished tubes shall be coated both on the outside and the inside diameter to prevent corrosion in transit. The type of coating applied should be mutually agreed upon and specified in the order.

11. Mechanical Tests Required

11.1 *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 (Note 1).

11.2 *Flattening Test*—One flattening test shall be made on specimens taken from each end of one finished tube, not the

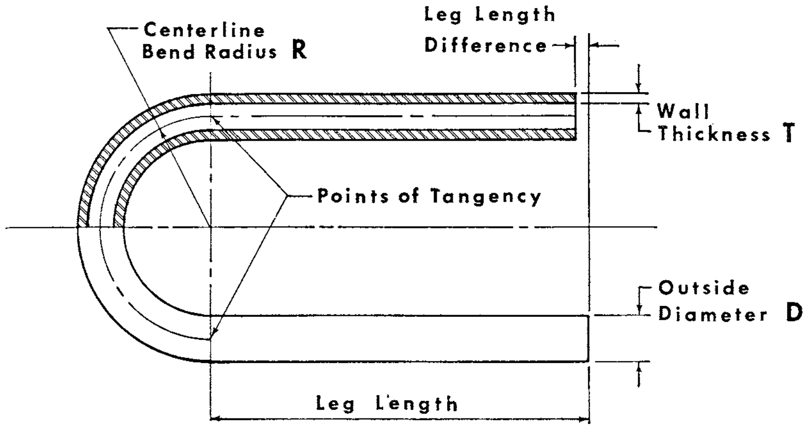

FIG. 1 Bent Portion of U-Tube

TABLE 4 Tube Leg Length Tolerance

Leg Length, ft [m]	Plus Tolerance in. [mm]
Up to 20 [6], incl	1⁄8 [3.2]
Over 20 to 30 [6 to 9], incl	5⁄32 [4.0]
Over 30 to 40 [9 to 12.2], incl	3⁄16 [4.8]

TABLE 5 Squareness of Ends Tolerance

Tube OD, in. [mm]	Tolerance, in. [mm]
5⁄8 [15.9]	0.010 [0.25]
Over 5⁄8 to 1¼ [15.9 to 31.7], incl	0.016 [0.4]

one used for the flaring test, from each lot of not more than 125 tubes or fraction thereof.

11.3 *Flaring Test*—One flaring test shall be made on specimens taken from each end of one finished tube, not the one used for flattening test, from each lot of not more than 125 tubes or fraction thereof.

11.4 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 1).

11.5 *Hydrostatic Test*—Each U-tube shall be subjected to a hydrostatic test, using a noncorrosive fluid, or when agreed upon between the purchaser and manufacturer, they may be tested at 1½ times the specified design working pressure.

12. Nondestructive Test (Electric Test)

12.1 Each tube shall be tested after the finish heat treatment following the final cold-drawn pass by passing through a nondestructive tester capable of detecting defects on the entire cross section of the tube, in accordance with Specification A 450/A 450M.

13. Packaging and Package Marking

13.1 The tubing shall be packaged or bundled in such a manner as to prevent damage in ordinary handling and transportation and identified by a tag with the name of the manufacturer, purchase order number, specification number and grade, and size.

13.2 In the case of U-tubes, each box shall be palletized and legibly marked showing the manufacturer's name, purchase order number, specification number and grade, size, and identification of items contained.

13.3 *Bar Coding*—In addition to the requirements in 13.1 and 13.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

14. Keywords

14.1 carbon; feedwater heater tubes; seamless steel tube; steel tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement or requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order, in which even the necessary tests shall be made by the manufacturer prior to the bending or shipment of the tubing.

S1. Nondestructive Ultrasonic Test—Round Tubing (Commercial Grade)

S1.1 The manufactuer shall test the tubing by an ultrasonic nondestructive test for detection of harmful faults and soundness.

S1.1.1 Ultrasonic testing shall be performed using pulse-echo shear wave techniques to locate longitudinal or circumferential defects, or both.

S1.1.2 Tubes being tested shall be reasonably straight for proper rotation. The outside and inside diameter surfaces of the tubes shall be free of dirt, grit, grease, oil, loose scale, or other materials which tend to attenuate, scatter, or reflect ultrasonic signals.

S1.1.3 Tubing shall be inspected by feeding spirally past a suitable transducer with rotation of material to be toward the transducer.

S1.1.4 Suitable ultrasonic instrumentation shall be used to clearly distinguish the artificial defects (hereafter called reference notches) described later. Automatic electronic monitoring of the reflected ultrasonic signals shall be provided in such manner that any naturally occurring defects which present an ultrasonic reflection equal to or greater than the reference standard(s) shall trigger audible and visible alarms.

S1.1.5 Instrument calibration as described herein shall be accomplished with the reference standard being rotated and fed past the transducer at the same approximate rate at which the tubing under test will be tested.

S1.1.6 The following factors will be adjusted so as to achieve optimum instrument distinction between the reference notch(es) and plain portion of tubing when calibrating equipment to the reference standard:

S1.1.6.1 Search unit position shall be such that shear waves are propagated within the tube being tested. If both outside and inside diameter reference notches are used, the optimum angle shall be used which will indicate both notches as close to equal size as possible.

S1.1.6.2 The test frequency to be used shall be chosen to yield the best distinction between reference notches and plain areas of tubing. In general, 2.25 or 5.0 MHz will be used.

S1.1.6.3 Instrument sensitivity shall be adjusted to allow reference notch or notches to present a pip or pips on the scope screen at 50 % to 70 % of instrument saturation level. The Automatic Defect Monitoring System shall be adjusted to monitor by means of electronic gates, the portion of the screen where the reference notch is presented. The sensitivity of the alarm system shall be adjusted to indicate audibly and visibly when the reference notch is fed past the search unit.

S1.1.6.4 The recording equipment, if agreed upon, shall be adjusted to clearly indicate the reference notch or notches and also whether or not any reflected signals actuate the alarm system.

S1.1.7 A reference standard of an appropriate length (sufficient to allow in-line feeding) shall be prepared from a randomly selected tube of the same size, grade, and physical condition as the material to be tested.

S1.1.8 The reference standard shall contain machined notches as follows: Notch to be 10 % of wall thickness in depth but not less than 0.004 in. [0.10 mm]. Tolerance on depth +0.0000 in. or −0.001 in. [0.03 mm].

S1.1.8.1 *Notch Locations and Orientation*—Notches shall be located on outside or inside diameter, or both, and shall be oriented to lie in a longitudinal direction for radial inspection or circumferentially, or both, for transverse inspection. The notch or notches shall be located in the reference tube in such a manner that no physical or acoustical interference exists between notches or end of reference tube. These various locations and orientations will be classified as follows:

Type A—Longitudinal outside diameter for radial inspection,

Type B—Longitudinal inside diameter for radial inspection,

Type C—Circumferential outside diameter for transverse inspection, and

Type D—Circumferential inside diameter for transverse inspection.

S1.1.8.2 *Standard Nomenclature*—The size, location, and orientation of the reference notches, which become a part of a particular order covered under this specification, shall be specified.

S1.1.9 The basic procedure will be to rotary feed all the tubes in the order past the search unit (transducer) with the feed helix less than the scanning width of the search unit. As the tubes are fed past the transducer, the alarm system shall be observed for indications of defects equal to or greater than the reference standard. Tubes which show such indications shall be rejected.

S1.1.10 Standard procedure will be to test the material in one direction of helical feed only. Testing in both directions may be done if so specified by customer.

S1.1.11 Any tubes that do not show indications above the level determined by the reference standard shall be held in a lot until the reference standard is run and instrument calibration is proved by triggering alarm system on the reference notch or notches. After calibration is proved to have been correct, this lot of tubes shall be considered tested and accepted as to maximum defect size corresponding to the reference standard used.

S1.1.12 Rejected tubing may be salvaged by polishing or other suitable means when practical and retested after the elimination of the cause of rejection. Such material that meets the dimensional requirements and does not cause triggering of ultrasonic alarm system upon retesting shall be considered as having met the requirements of this supplement.

S2. Nondestructive Ultrasonic Test—Round Tubing (Select Commercial Grade)

S2.1 The manufacturer shall test the tubing using the procedure outlined in Supplementary Requirement S1, except for the notch depth, which shall be 5 % of wall thickness in depth but not less than 0.004 in. [0.10 mm]. Tolerance on depth shall be +0.000 in. or −0.0005 in. [0.01 mm].

S3. Nondestructive Eddy-Current Test

S3.1 Each tube shall be tested after the finish heat treatment following the final cold-draw pass by passing through an electric nondestructive tester capable of detecting defects on the entire cross section of the tube. Suitable instrumentation shall be used to clearly distinguish artificial defects or reference notches. Tubes to be tested shall be reasonably straight and the outside and inside diameter surfaces shall be free of loose scale, metallic particles, or other material which would tend to restrict signals or create electrical noise. The tubing shall be inspected by feeding longitudinally through an inspection coil or coils of a diameter suitable for the diameter of tubing to be inspected. The instrument calibration shall be accomplished with a reference standard prepared from an appropriate length of selected tubing of the same size, grade, and physical condition as the material to be inspected. The standard shall be fed through the coil at the same speed at which the inspection of the tubing is performed. The following factors shall be selected or adjusted, or both, in accordance with the instrument manufacturer's instructions for the particular instrument involved as required to achieve optimum instrument distinction between the reference defects and plain portion of the tube. These as well as other factors involved shall not be used in such a manner that they detract from the instrument's overall ability to detect injurious defects:

S3.1.1 Test frequency,
S3.1.2 Direct-current saturation level,
S3.1.3 Filter networks,
S3.1.4 Phase analysis circuits,
S3.1.5 Coil diameter, and
S3.1.6 Instrument gain.

S3.2 The reference standard shall contain longitudinal and circumferential notches in the outside diameter and shall be used to establish the rejection level for the tubing to be tested. Inside diameter notches, both longitudinal and circumferential, shall also be a part of the reference standard. These notches may be larger than outside diameter notches and are intended for use only to assure instrument phase settings capable of yielding optimum inside diameter surface sensitivity. The outside diameter reference notches shall have a depth equal to 10 % of the wall thickness. The tolerance of the notch shall be ±8 % or 0.0005 in. [0.01 mm], whichever is greater. Width of notch shall not exceed twice the depth. The length of the reference notches shall not exceed 0.375 in. [9.5 mm]. All tubing including that which may be reconditioned, provided the dimensional or other properties of the tubing are not adversely affected and provided the tubing does not show indications above the level determined by the outside diameter references, shall meet this specification provided the instrument calibration is verified by indicating the standard outside diameter reference notches of a given lot. Tubes generating a signal above the calibration standard sensitivity level shall be rejected. Tubes may be reconditioned if not adversely affecting the dimensional or other properties of the tube and so tested as to assure a satisfactory tube within the limits of this specification. All tubing shall be demagnetized after inspection has been completed.

Designation: A 554 – 03

Standard Specification for Welded Stainless Steel Mechanical Tubing[1]

This standard is issued under the fixed designation A 554; 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*

1.1 This specification covers welded stainless steel tubing for mechanical applications where appearance, mechanical properties, or corrosion resistance is needed. The grades covered are listed in Table 1.

1.2 This specification covers as-welded or cold-reduced mechanical tubing in sizes to 16 in. (406.4 mm) outside dimension, and in wall thicknesses 0.020 in. (0.51 mm) and over.

1.3 Tubes shall be furnished in one of the following shapes as specified by the purchaser: round, square, rectangular, or special.

1.4 Supplementary requirements of an optional nature are provided and when desired shall be so stated in the order.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[3]

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[3]

2.2 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[4]

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[4]

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[4]

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, mass, or number of pieces),

3.1.2 Name of material (welded stainless steel mechanical tubing),

3.1.3 Form (round, square, rectangular, special, see 1.3),

3.1.4 Dimensions:

3.1.4.1 Round-outside diameter and wall thickness for all conditions (Section 8). Alternatively, for cold-reduced condition, outside diameter and inside diameter or inside diameter and wall dimensions may be specified,

3.1.4.2 Square and rectangular outside dimensions and wall thickness (see 9.1),

3.1.4.3 Special (to be specified),

3.1.5 Length (mill lengths, cut lengths, or multiple lengths (see 8.3)),

3.1.6 Grade (Table 1),

3.1.7 Condition (see 6.1),

3.1.8 Inside diameter bead condition (see 6.2),

3.1.9 Surface finish (see Section 11),

3.1.10 Report of chemical analysis, if required (Section 7),

3.1.11 Individual supplementary requirements, if required,

3.1.12 End use,

3.1.13 Specification designation,

3.1.14 Special requirements,

3.1.15 Special marking (Section 14), and

3.1.16 Special packing (Section 15).

4. Process

4.1 The steel may be made by any process.

4.2 If a specific type of melting is required by the purchaser, it shall be stated on the purchase order.

4.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, such as electroslag remelting or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

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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 Tubing.

Current edition approved Sept. 10, 2003. Published October 2003. Originally approved in 1965. Last previous edition approved in 1998 as A 554 – 98$^{\epsilon 1}$.

[2] 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.

[3] Withdrawn

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111–5094, Attn: NPODS.

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

TABLE 1 Chemical Requirements

Grade	Carbon, max	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Titanium	Columbium + Tantalum
	Composition, %									
Austenitic										
MT-301	0.15	2.00	0.040	0.030	1.00	6.0–8.0	16.0–18.0	...	...	...
MT-302	0.15	2.00	0.040	0.030	1.00	8.0–10.0	17.0–19.0	...	...	...
MT-304	0.08	2.00	0.040	0.030	1.00	8.0–11.0	18.0–20.0	...	...	...
MT-304L	0.035[A]	2.00	0.040	0.030	1.00	8.0–13.0	18.0–20.0	...	...	...
MT-305	0.12	2.00	0.040	0.030	1.00	10.0–13.0	17.0–19.0	...	...	...
MT-309S	0.08	2.00	0.040	0.030	1.00	12.0–15.0	22.0–24.0	...	...	...
MT-309S-Cb	0.08	2.00	0.040	0.030	1.00	12.0–15.0	22.0–24.0	...	...	[B]
MT-310S	0.08	2.00	0.040	0.030	1.00	19.0–22.0	24.0–26.0	...	...	...
MT-316	0.08	2.00	0.040	0.030	1.00	10.0–14.0	16.0–18.0	2.0–3.0	...	...
MT-316L	0.035[A]	2.00	0.040	0.030	1.00	10.0–15.0	16.0–18.0	2.0–3.0	...	...
MT-317	0.08	2.00	0.040	0.030	1.00	11.0–14.0	18.0–20.0	3.0–4.0	...	...
MT-321	0.08	2.00	0.040	0.030	1.00	9.0–13.0	17.0–20.0	...	[C]	...
MT-330	0.15	2.00	0.040	0.030	1.00	33.0–36.0	14.0–16.0	...	...	...
MT-347	0.08	2.00	0.040	0.030	1.00	9.0–13.0	17.0–20.0	...	...	[B]
Ferritic										
MT-429	0.12	1.00	0.040	0.030	1.00	0.50 max	14.0–16.0	...	...	...
MT-430	0.12	1.00	0.040	0.030	1.00	0.50 max	16.0–18.0	...	...	...
MT-430-Ti	0.10	1.00	0.040	0.030	1.00	0.075 max	16.0–19.5	...	5 × C min, 0.75 max	...

[A] For small diameter or thin walls, or both, where many drawing passes are required, a carbon content of 0.040 % max is necessary in grades MT-304L and MT-316L. Small outside diameter tubes are defined as those less than 0.500 in. (12.7 mm) in outside diameter and light wall tubes as those less than 0.049 in. (1.24 mm) in average wall thickness.
[B] The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.00 %.
[C] The titanium content shall be not less than five times the carbon content and not more than 0.60 %.

4.4 Steel may be cast in ingots or may be strand cast. When steel of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

5. Materials and Manufacture

5.1 The tubes shall be made from flat-rolled steel by an automatic welding process without the addition of filler metal.

6. Condition

6.1 The tubes shall be furnished in any of the following conditions as specified:

6.1.1 As welded,

6.1.2 Welded and annealed,

6.1.3 Cold reduced,

6.1.4 Cold reduced and annealed.

6.2 The inside diameter bead shall be furnished in any of the following conditions as specified:

6.2.1 Bead not removed,

6.2.2 Bead controlled to 0.005 in. (0.13 mm) or 15 % of the specified wall thickness, whichever is greater, and

6.2.3 Bead removed.

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall conform to requirements specified. When requested in the order or contract, a report of this analysis shall be furnished to the purchaser. (See Test Methods E 30 and Practice E 59.)

8. Permissible Variations in Dimensions—Round Tubing

8.1 For all conditions except tubing with bead removed, Table 2 shall apply.

8.2 For tubing with bead removed, Table 3 shall apply.

8.3 *Lengths*—Tubing is normally furnished in mill lengths 5 ft (1.5 m) and over. Definite cut lengths are furnished when specified, to the length tolerances shown in Table 4. For tubing ordered in multiple lengths, it is common practice to allow a definite amount over for each multiple for the purchaser's cutting operation. Thus cutting allowance should be specified in the purchase order.

8.4 *Straightness Tolerance*—The straightness tolerance shall be 0.030 in. (0.76 mm) maximum in any 3-ft (0.9-m) length of tubing. The straightness tolerance on shorter lengths and on special requirements shall be agreed upon between the purchaser and producer.

9. Permissible Variations in Dimensions—Square and Rectangular Tubing

9.1 Square and rectangular welded stainless mechanical tubing is supplied as cold worked unless otherwise specified. For this tubing, variations in dimensions from those specified shall not exceed the amounts prescribed in Table 5. For lengths, see 8.3.

10. Workmanship, Finish, and Appearance

10.1 Finished tubes shall have smooth ends free of burrs. They shall be free of injurious defects and shall have a

TABLE 2 Diameter, Wall,^{A} and Ovality Tolerances (All Conditions Except Tubing with Bead Removed)

NOTE 1—Ovality is the difference between maximum and minimum outside diameters measured at any one cross section. There is no additional tolerance for ovality on tubes having a specified wall thickness of more than 3 % of the outside diameter.

NOTE 2—For sizes up to and including 5-in. (127.0-mm) outside diameter, an ovality tolerance of twice the tabular outside diameter tolerance spread shown is applied one half plus and one half minus to tubes having a specified wall thickness of 3 % or less of the specified outside diameter. The average of the maximum and minimum outside diameter readings should fall within the outside diameter tolerances as shown in this table.

NOTE 3—For sizes over 5-in. (127.0-mm) to and including 16-in. (406.4-mm) outside diameter, when the specified wall thickness is 3 % or less of the outside diameter, the ovality shall not exceed 1.5 % of the specified outside diameter.

OD Size, in. (mm)	Wall Thickness		OD, ±	
	in.	mm	in.	mm
Under ½ (12.7)	0.020 to 0.049	0.51 to 1.24	0.004	0.10
½ to 1 (12.7 to 25.4)	0.020 to 0.065	0.51 to 1.65	0.005	0.13
½ to 1 (12.7 to 25.4)	over 0.065 to 0.134	over 1.65 to 3.40	0.010	0.25
Over 1 to 1 ½ (25.4 to 38.1), incl	0.025 to 0.065	0.64 to 1.65	0.008	0.20
Over 1 to 1 ½ (25.4 to 38.1), incl	over 0.065 to 0.134	over 1.65 to 3.40	0.010	0.25
Over 1 ½ to 2 (38.1 to 50.8), incl	0.025 to 0.049	0.64 to 1.24	0.010	0.25
Over 1 ½ to 2 (38.1 to 50.8), incl	over 0.049 to 0.083	over 1.24 to 2.11	0.011	0.28
Over 1 ½ to 2 (38.1 to 50.8), incl	over 0.083 to 0.149	over 2.11 to 3.78	0.012	0.30
Over 2 to 2 ½ (50.8 to 63.5), incl	0.032 to 0.065	0.81 to 1.65	0.012	0.30
Over 2 to 2 ½ (50.8 to 63.5), incl	over 0.065 to 0.109	over 1.65 to 2.77	0.013	0.33
Over 2 to 2 ½ (50.8 to 63.5), incl	over 0.109 to 0.165	over 2.77 to 4.19	0.014	0.36
Over 2 ½ to 3 ½ (63.5 to 88.9), incl	0.032 to 0.165	0.81 to 4.19	0.014	0.36
Over 2 ½ to 3 ½ (63.5 to 88.9), incl	over 0.165	over 4.19	0.020	0.51
Over 3 ½ to 5 (88.9 to 127.0), incl	0.035 to 0.165	0.89 to 4.19	0.020	0.51
Over 3 ½ to 5 (88.9 to 127.0), incl	over 0.165	over 4.19	0.025	0.64
Over 5 to 7 ½ (127.0 to 190.5), incl	0.049 to 0.250	1.24 to 6.35	0.025	0.64
Over 5 to 7 ½ (127.0 to 190.5), incl	over 0.250	over 6.35	0.030	0.76
Over 7 ½ to 16 (190.5 to 406.4), incl	all	all	0.00125 in./in. or mm/mm of circumference	

^{A} Wall tolerance ±10 % of specified wall thickness.

workmanlike finish. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale patterns will not be considered as serious defects, provided the imperfections are removable within 10 % of the specified wall or 0.002 in. (0.05 mm), whichever is greater. The removal of surface imperfections is not required, unless special finishes are specified.

11. Surface Finish

11.1 Tubes shall be free of scale.

11.2 If special surface conditioning is required, they shall be stated in the order.

12. Rejection

12.1 Tubing that fails to meet the requirements of this specification shall be set aside and the manufacturer notified.

13. Coating

13.1 Stainless steel tubing is commonly shipped without protective coating. If special protection is needed, details shall be specified in the order.

TABLE 3 Diameter, Wall,^{A} and Ovality Tolerances for Tubing with Bead Removed

NOTE 1—Ovality is the difference between maximum and minimum outside diameters measured at any one cross section. There is no additional tolerance for ovality on tubes having a specified wall thickness of more than 3 % of the outside diameter.

NOTE 2—An ovality allowance of twice the outside diameter tolerance, shown in this table, is applied one half plus and one half minus to the outside diameter, for tubes having a specified wall thickness of 3 % or less of the specified outside diameter. The average of the maximum and minimum outside diameter readings should fall within the outside diameter tolerances of this table.

NOTE 3—Tubing may be specified to only two of the three following dimensions—outside diameter, inside diameter, or wall.

OD Size, in. (mm)	OD, ±		ID, ±	
	in.	mm	in.	mm
Up to 3⁄32 (2.4), excl	0.001	0.03	0.001	0.03
3⁄32 to 3⁄16 (2.4 to 4.8), excl	0.0015	0.038	0.0015	0.038
3⁄16 to ½ (4.8 to 12.7), excl	0.003	0.08	0.005	0.13
½ to 1 (12.7 to 25.4), excl	0.004	0.10	0.006	0.15
1 to 1½ (25.4 to 38.1), excl	0.005	0.13	0.007	0.18
1 ½ to 2 (38.1 to 50.8), excl	0.006	0.15	0.008	0.20
2 to 2 ½ (50.8 to 63.5), excl	0.007	0.18	0.010	0.25
2 ½ to 3 ½ (63.5 to 88.9), excl	0.010	0.25	0.014	0.36
3 ½ to 5 (88.9 to 127.0), incl	0.015	0.38	0.020	0.51
Over 5 to 16 (127.0 to 406.4), incl	0.00125 in./in. or mm/mm of circumference		0.0013 in./in. or mm/mm of circumference	

^{A} Wall tolerance is ±10 % of specified wall thickness.

TABLE 4 Length Variations—Cut Length Tubes

Length, ft (m)	Outside Diameter, in. (mm)	Permissible Variations in Length, in. Over[A] in.	Over[A] mm	Under
4 (1.2) and under	up to 2 (50.8), incl	1⁄16	1.6	0
	over 2 to 4 (50.8 to 101.6), incl	3⁄32	2.4	0
	over 4 (101.6)	1⁄8	3.2	0
Over 4 to 10 (1.2 to 3.0), incl	up to 2 (50.8), incl	3⁄32	2.4	0
	over 2 (50.8)	1⁄8	3.2	0
Over 10 to 24 (3.0 to 7.3), incl	all sizes	3⁄16	4.8	0

[A] For all diameters in lengths over 24 ft (7.3 m), an additional over tolerance of 1⁄8 in. (3.2 mm) for each 10 ft (3.0 m) or fraction thereof shall be permissible, up to a tolerance of 1⁄2 in. (12.7 mm), max.

14. Product Marking

14.1 *Civilian Procurement*—Each box, bundle or lift, and piece (when individual pieces are shipped) shall be identified by a tag or stencil with the manufacturer's name or brand, specified size, purchaser's order number, this specification number, and grade. Bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

14.2 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for Military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

15. Packaging

15.1 *Civilian Procurement*—On tubing of 0.065-in. (1.65-mm) wall and lighter, the manufacturer will, at his option, box, crate, carton, package in secure lifts or bundles to ensure safe delivery. Tubing heavier than 0.065-in. wall will normally be shipped loose, bundled, or in secured lifts. Special packaging requiring extra operations other than those normally used by the manufacturer must be specified in the order.

15.2 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the government when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

TABLE 5 Square and Rectangular Tubing

Outside Dimension Tolerances

Largest Specified Outside Dimension Across Flats, in. (mm)	Wall Thickness, in. (mm)	±, in. (mm), across Flats, Convexity or Concavity, incl
To 1 1⁄4 (31.8), incl	all	0.015 (0.38)
Over 1 1⁄4 to 2 1⁄2 (31.8 to 63.5), incl	all	0.020 (0.51)
Over 2 1⁄2 to 5 1⁄2 (63.5 to 139.7), incl	all	0.030 (0.76)
Over 5 1⁄2 to 8 (139.7 to 203.2), incl	all	0.060 (1.52)

Wall Thickness Tolerance

± 10 % of specified wall thickness

Maximum Radii of Corners

Wall Thickness, in. (mm)	Radii of Corners, max, in. (mm)
Over 0.020 to 0.049 (0.51 to 1.24), incl	3⁄32 (2.4)
Over 0.049 to 0.065 (1.24 to 1.65), incl	1⁄8 (3.2)
Over 0.065 to 0.083 (1.65 to 2.11), incl	9⁄64 (3.6)
Over 0.083 to 0.095 (2.11 to 2.42), incl	3⁄16 (4.8)
Over 0.095 to 0.109 (2.42 to 2.77), incl	13⁄64 (5.2)
Over 0.109 to 0.134 (2.77 to 3.40), incl	7⁄32 (5.6)
Over 0.134 to 0.156 (3.40 to 3.96), incl	1⁄4 (6.4)
Over 0.156 to 0.200 (3.96 to 5.08), incl	3⁄8 (9.5)
Over 0.200 to 0.250 (5.08 to 6.35), incl	1⁄2 (12.7)
Over 0.250 to 0.375 (6.35 to 9.53), incl	3⁄4 (19.1)

Twist Tolerances

Largest Size, in. (mm)	Twist in 3 ft, max, in. (mm/m)
Under 1⁄2 (12.7)	0.050 (1.4)
1⁄2 to 11⁄2 (12.7 to 38.1), incl	0.075 (2.1)
Over 1 1⁄2 to 2 1⁄2 (38.1 to 63.5), incl	0.095 (2.6)
Over 2 1⁄2 to 4 (63.5 to 101.6), incl	0.125 (3.5)
Over 4 to 6 (101.6 to 152.4) incl	0.250 (6.9)
Over 6 (152.4)	0.375 (10.4)

Squareness of Sides

$$\pm B = C \times 0.006$$

where:
B = tolerance for out-of-square, and
C = length of longest side.

The straightness tolerance is 0.075 in. in 3 ft or 2.1 mm in 1 m using a 3-ft (1-m) straightedge and feeler gage.

16. Keywords

16.1 austenitic stainless steel; mechanical tubing; stainless steel tube; steel tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order and the necessary tests made at the mill. Mechanical tests shall be performed in accordance with the applicable sections of Test Methods and Definitions A 370.

S1. Hardness Test

S1.1 Round annealed tubes shall conform to the requirements as to the hardness limits prescribed in Table S1.1.

NOTE S1—There are tubing diameters, walls, or combinations which limit the applicability of particular hardness values.

S1.2 When specified, the hardness test shall be performed on a specimen from one tube from each 2500 ft (760 m) or fraction thereof from each heat of steel.

S2. Tension Test

S2.1 The tubes shall conform to the requirements as to tensile properties prescribed in Table S2.1. When cold-reduced tempers are ordered, the manufacturer shall be consulted.

S2.2 When the tension test is specified, one test shall be performed on a specimen from one tube of each lot of 2500 ft (760 m) or fraction thereof from each heat of steel, prior to cutting to length.

S2.3 The yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen or to a total extension of 0.5 % of the gage length under load shall be determined.

S3. Nondestructive Test

S3.1 Various types of nondestructive test are available. When any such test is required, the test to be used and the inspection limits shall be specified in the order.

S4. Test Reports

S4.1 Mill test reports will be furnished when specified in the order.

S4.2 When specified on the purchase order, or when a specific type of melting has been specified, the type of melting used to produce the material shall be included with the test report.

TABLE S1.1 Hardness Requirements (Round Annealed Condition)

Grade	Hardness	
	Brinell, max	Rockwell B, max
All austenitic	192	90
MT 429 and MT 430	190	90
MT-430-Ti	190	90

TABLE S2.1 Tensile Requirements (Round Annealed Condition)

Grade	Tensile Strength, min		Yield Strength, min		Elongation[A] in 2 in. or 50 mm, min, %
	ksi	MPa	ksi	MPa	
MT 429 and MT 430	60	414	35	241	20
MT-430-Ti	60	414	30	207	20
MT 304 L & MT 316 L	70	483	25	172	35
All other austenitic steels	75	517	30	207	35

[A] For longitudinal strip tests, the width of the gage section shall be 1 in. (25.4 mm) and a deduction of 1.75 percentage points for austenitic grades and 1.0 percentage points for MT 429 and MT 430 shall be permitted from the basic minimum elongation for each 1⁄32-in. (0.79-mm) decrease in wall thickness below 5⁄16 in. (7.94 mm).

S5. Certification for Government Orders

S5.1 A producer's or supplier's certification shall be furnished to the government that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. This certificate shall include a report of heat analysis (product analysis when requested in the purchase order), and, when specified in the purchase order or contract, a report of test results shall be furnished.

S6. Rejection Provisions for Government Orders

S6.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the tube may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

S6.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside, and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such material shall be a matter for agreement.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 554 – 98$^{\epsilon 1}$, that may impact the use of this specification. (Approved September 10, 2003)

(*1*) Added a wall tolerance section to Table 5.

Designation: A 540/A 540M – 06

Standard Specification for Alloy-Steel Bolting Materials for Special Applications[1]

This standard is issued under the fixed designation A 540/A 540M; 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 regular and special-quality alloy steel bolting materials which may be used for nuclear and other special applications. Bolting materials as used in this specification cover rolled or forged bars, rotary pierced or extruded seamless tubes, bored bars, or forged hollows from forged or rolled bar segments to be manufactured into bolts, studs, washers, and nuts.

1.2 Several grades of steel are covered. The grade and class shall be specified by the purchaser.

1.3 Supplementary requirements of an optional nature are provided for use when special quality is desired. These supplementary requirements call for additional tests to be made and when desired shall be so stated in the order, together with the acceptance limits required.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable" M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 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.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range

E 45 Test Methods for Determining the Inclusion Content of Steel

2.2 *AIAG Standard:*

AIAG B-5 02.00 Primary Metals Identification Tag Application Standard[4]

2.3 *ANSI Standards:*[5]

B 1.1 Unified Screw Threads

B 18.2.1 Square and Hex Bolts and Screws Including Hex Cap Screws and Lag Bolts

B 18.2.2 Square and Hex Nuts

B 18.3 Hexagon Socket and Spline Socket Screws

3. Ordering Information

3.1 The inquiry and orders for material under this specification shall include the following, as required, to describe the desired material adequately:

3.1.1 Condition (Section 5),

3.1.2 Heat treatment (Section 6),

3.1.3 Supplementary Requirements (S1 to S9),

3.1.4 Reports required (Section 17),

3.1.5 End use, and

3.1.6 Any special requirements.

3.2 The purchaser is referred to the listed supplementary requirements.

4. Common Requirements

4.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A 962/A 962M, this specification shall prevail.

5. Manufacture

5.1 The material shall be supplied hot-rolled or hot-forged or cold-finished at the option of the producer. However, if desired by the purchaser, cold finishing may be specified.

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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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] For ASME Boiler and Pressure Vessel Code Applications see related Specification SA-540 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 Automotive Industry Action Group, 26200 Lahser, Suite 200, Southfield, MI 48034.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

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

6. Heat Treatment

6.1 Material which is ordered in the annealed condition shall have a structure suitable for machining. Such annealed bolting material is not intended to be used without subsequent quenching and tempering as specified in 6.2

6.2 Material which is ordered in the liquid-quenched and tempered condition shall be uniformly reheated from a temperature below the cooling transformation range to the proper austenitizing temperature. It shall be quenched in a liquid medium under substantially uniform conditions and then uniformly reheated for tempering. The minimum tempering temperature shall be 850 °F [455 °C].

6.3 Material that has been straightened after quenching and tempering shall be stress relieved by reheating to a temperature not lower than 100 °F [55 °C] under the tempering temperature.

7. Chemical Composition

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

8. Tensile Requirements

8.1 Material furnished in the annealed condition shall be capable of meeting the specified tensile properties for the class as specified in Table 2 when heat treated in accordance with 6.2 and 6.3 (see Supplementary Requirement S4).

8.2 Material in the quenched and tempered or quenched, tempered and stress-relieved condition shall conform to properties shown in Table 2 for the specified class.

9. Hardness Requirements

9.1 The hardness shall be determined on the surface of the material after removal of decarburization.

9.2 The hardness of material in the annealed condition shall not be greater than 235 HB.

9.3 The hardness of material in the quenched and tempered or quenched, tempered and stress-relieved condition shall be within the limits in Table 2 for the specified class.

10. Impact Requirements

10.1 Annealed material after proper heat treatment shall be capable of meeting the impact requirements in Table 2 or of Supplementary Requirement S8, if so specified (see Supplementary Requirement S4).

10.2 Material in the quenched and tempered or quenched, tempered, and stress-relieved condition shall conform to the impact requirements in Table 2, or of Supplementary Requirement S8 if so specified.

10.3 The percent of shear (ductility or fibrous) fracture shall be computed. The computed value shall be recorded for all impact specimens.

10.4 The amount of lateral expansion shall be measured. The measured value shall be recorded for all impact specimens.

10.5 The percent shear and the amount of lateral expansion shall be reported for information purposes (see 17.1).

TABLE 1 Chemical Requirements[A]

Identification Symbol Grade	B21		B22		B23		B24		B24V	
	(Cr-Mo-V)		(4142-H)		(E-4340-H)		(4340 Mod.)		(4340V Mod.)	
	Chromium-Molybdenum-Vanadium		Chromium-Molybdenum		Chromium-Nickel-Molybdenum		Chromium-Nickel-Molybdenum		Chromium-Nickel-Molybdenum-Vanadium	
	Range, %	Product Variation, Over or Under,[B] %	Range, %	Product Variation, Over or Under,[B] %	Range, %	Product Variation, Over or Under,[B] %	Range, %	Product Variation, Over or Under,[B] %		Product Variation, Over or Under,[B] %
Carbon	0.36–0.44	0.02	0.39–0.46	0.02	0.37–0.44	0.02	0.37–0.44	0.02	0.37–0.44	0.02
Manganese	0.45–0.70	0.03	0.65–1.10	0.04	0.60–0.95	0.04	0.70–0.90	0.04	0.60–0.95	0.04
Phosphorus, max	0.025[C]	0.005	0.025[C]	0.005	0.025[C]	0.005	0.025[C]	0.005	0.025[C]	0.005
Sulfur, max	0.025[C]	0.005	0.025[C]	0.005	0.025[C]	0.005	0.025[C]	0.005	0.025[C]	0.005
Silicon	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35[D]	0.02
Chromium	0.80–1.15	0.05	0.75–1.20	0.05	0.65–0.95	0.05	0.70–0.95	0.05	0.60–0.95	0.05
Nickel	. . .	. . .	. . .	. . .	1.55–2.00	0.05	1.65–2.00	0.05	1.55–2.00	0.05
Molybdenum	0.50–0.65	0.03	0.15–0.25	0.02	0.20–0.30	0.02	0.30–0.40	0.02	0.40–0.60	0.03
Vanadium	0.25–0.35	0.03	. . .	. . .	. . .	. . .	. . .	. . .	0.04–0.10	0.01

[A] The intentional addition of Bi, Se, Te, and Pb is not permitted.
[B] Unless otherwise specified, separate determinations may vary from the specified ranges, except that elements in any heat must not vary both above and below the specified range.
[C] Phosphorus and sulfur content is 0.04 % max when open-hearth steel is specified.
[D] Silicon content is 0.35 % max if vacuum-carbon deoxidized.

TABLE 2 Mechanical Property Requirements

NOTE 1—The minimum average of 3 specimens shall not be less than 35 ft·lbf [47 J]. One specimen from a set of 3 may be less than 35 ft·lbf [47 J] but not less than 30 ft·lbf [41 J].

NOTE 2— The minimum average of 3 specimens shall not be less than 30 ft·lbf [41 J]. One specimen from a set of 3 may be less than 30 ft·lbf [41 J] but not less than 25 ft·lbf [34 J].

NOTE 3—The minimum average of 3 specimens shall not be less than 25 ft·lbf [34 J]. One specimen from a set of 3 may be less than 25 ft·lbf [34 J] but not less than 20 ft·lbf [27 J].

NOTE 4—No minimum values established. Tests shall be run for information only.

Grade	Class	Diameter	Tensile Strength, min	Yield Strength, 0.2 % offset, min	Elongation, min, %	Reduction of Area, min, %	Surface Brinell Hardness min	Surface Brinell Hardness max	Charpy V-Notch +10 °F [−12.2 °C]
Inch-Pound Units									
		in.	ksi	ksi	In 2 in.				
B21 (Cr-Mo-V)	5	to 2, incl	120	105	15	50	241	285	Note 4
		over 2 to 6, incl	115	100	15	50	248	302	Note 4
		over 6 to 8, incl	115	100	15	50	255	311	Note 4
	4	to 3, incl	135	120	13	45	269	331	Note 4
		over 3 to 6, incl	135	120	13	45	277	352	Note 4
	3	to 3, incl	145	130	12	40	293	352	Note 4
		over 3 to 6, incl	145	130	12	40	302	375	Note 4
	2	to 4, incl	155	140	11	40	311	401	Note 4
	1	to 4, incl	165	150	10	35	321	429	Note 4
B22 (4142-H)	5	to 2, incl	120	105	15	50	248	293	Note 1
		over 2 to 4, incl	115	100	15	50	255	302	Note 4
	4	to 1, incl	135	120	13	45	269	341	Note 1
		over 1 to 4, incl	135	120	13	45	277	363	Note 4
	3	to 2, incl	145	130	12	40	293	363	Note 4
		over 2 to 4, incl	145	130	12	40	302	375	Note 4
	2	to 3, incl	155	140	11	40	311	401	Note 4
	1	to 1½ , incl	165	150	10	35	321	401	Note 4
B23 (E-4340-H)	5	to 6, incl	120	105	15	50	248	311	Note 1
		over 6 to 8, incl	115	100	15	50	255	321	Note 1
		over 8 to 9½ , incl	115	100	15	50	262	321	Note 4
	4	to 3, incl	135	120	13	45	269	341	Note 1
		over 3 to 6, incl	135	120	13	45	277	352	Note 1
		over 6 to 9½ , incl	135	120	13	45	285	363	Note 4
	3	to 3, incl	145	130	12	40	293	363	Note 2
		over 3 to 6, incl	145	130	12	40	302	375	Note 2
		over 6 to 9½ , incl	145	130	12	40	311	388	Note 4
	2	to 3, incl	155	140	11	40	311	388	Note 4
		over 3 to 6, incl	155	140	11	40	311	401	Note 4
		over 6 to 9½ , incl	155	140	11	40	321	415	Note 4
	1	to 3, incl	165	150	10	35	321	415	Note 4
		over 3 to 6, incl	165	150	10	35	331	429	Note 4
		over 6 to 8, incl	165	150	10	35	341	444	Note 4
B24 (4340 Mod.)	5	to 6, incl	120	105	15	50	248	311	Note 1
		over 6 to 8, incl	115	100	15	50	255	321	Note 1
		over 8 to 9½ , incl	115	100	15	50	262	321	Note 1
	4	to 3, incl	135	120	13	45	269	341	Note 1
		over 3 to 6, incl	135	120	13	45	277	352	Note 1
		over 6 to 8, incl	135	120	13	45	285	363	Note 1
		over 8 to 9½ , incl	135	120	13	45	293	363	Note 4
	3	to 3, incl	145	130	12	40	293	363	Note 2
		over 3 to 8, incl	145	130	12	40	302	388	Note 2
		over 8 to 9½ , incl	145	130	12	40	311	388	Note 4
	2	to 7, incl	155	140	11	40	311	401	Note 2
		over 7 to 9½ , incl	155	140	11	40	321	415	Note 4
	1	to 6, incl	165	150	10	35	321	415	Note 3
		over 6 to 8, incl	165	150	10	35	331	429	Note 4
B24V (4340V Mod.)	3	to 4, incl	145	130	12	40	293	363	Note 1
		over 4 to 8, incl	145	130	12	40	302	375	Note 2
		over 8 to 11, incl	145	130	12	40	311	388	Note 3
	2	to 4, incl	155	140	11	40	311	388	Note 2
		over 4 to 8, incl	155	140	11	40	311	401	Note 3
		over 8 to 11, incl	155	140	11	40	321	415	Note 4

TABLE 2 *Continued*

Grade	Class	Diameter	Tensile Strength, min	Yield Strength, 0.2 % offset, min	Elongation, min, %	Reduction of Area, min, %	Surface Brinell Hardness min	Surface Brinell Hardness max	Charpy V-Notch +10 °F [−12.2 °C]
	1	to 4, incl	165	150	10	35	321	415	Note 3
		over 4 to 8, incl	165	150	10	35	331	429	Note 4
		over 8 to 11, incl	165	150	10	35	331	444	Note 4
				Metric Units					
		mm	MPa	MPa	In 50 mm				
B21	5	to 50, incl	825	725	15	50	241	285	Note 4
(Cr-Mo-V)		over 50 to 150, incl	795	690	15	50	248	302	Note 4
		over 150 to 205, incl	795	690	15	50	255	311	Note 4
	4	to 75, incl	930	825	13	45	269	331	Note 4
		over 75 to 150, incl	930	825	13	45	277	352	Note 4
	3	to 75, incl	1000	895	12	40	293	352	Note 4
		over 75 to 150, incl	1000	895	12	40	302	375	Note 4
	2	to 100, incl	1070	965	11	40	311	401	Note 4
	1	to 100, incl	1140	1035	10	35	321	429	Note 4
B22	5	to 50, incl	825	725	15	50	248	293	Note 1
(4142-H)		over 50 to 100, incl	795	690	15	50	255	302	Note 4
	4	to 25, incl	930	825	13	45	269	341	Note 1
		over 25 to 100, incl	930	825	13	45	277	363	Note 4
	3	to 50, incl	1000	895	12	40	293	363	Note 4
		over 50 to 100, incl	1000	895	12	40	302	375	Note 4
	2	to 75, incl	1070	965	11	40	311	401	Note 4
	1	to 38, incl	1140	1035	10	35	321	401	Note 4
B23	5	to 150, incl	825	725	15	50	248	311	Note 1
(E-4340-H)		over 150 to 200 incl	795	690	15	50	255	321	Note 1
		over 200 to 240, incl	795	690	15	50	262	321	Note 4
	4	to 75, incl	930	825	13	45	269	341	Note 1
		over 75 to 150, incl	930	825	13	45	277	352	Note 1
		over 150 to 240, incl	930	825	13	45	285	363	Note 4
	3	to 75, incl	1000	895	12	40	293	363	Note 2
		over 75 to 150, incl	1000	895	12	40	302	375	Note 2
		over 150 to 240, incl	1000	895	12	40	311	388	Note 4
	2	to 75, incl	1070	965	11	40	311	388	Note 4
		over 75 to 150, incl	1070	965	11	40	311	401	Note 4
		over 150 to 240, incl	1070	965	11	40	321	415	Note 4
	1	to 75, incl	1140	1035	10	35	321	415	Note 4
		over 75 to 150, incl	1140	1035	10	35	331	429	Note 4
		over 150 to 200, incl	1140	1035	10	35	341	444	Note 4
B24	5	to 150, incl	825	725	15	50	248	311	Note 1
(4340 Mod.)		over 150 to 200, incl	795	690	15	50	255	321	Note 1
		over 200 to 240, incl	795	690	15	50	262	321	Note 1
	4	to 75, incl	930	825	13	45	269	341	Note 1
		over 75 to 150, incl	930	825	13	45	277	352	Note 1
		over 150 to 200, incl	930	825	13	45	285	363	Note 1
		over 200 to 240, incl	930	825	13	45	293	363	Note 4
	3	to 75, incl	1000	895	12	40	293	363	Note 2
		over 75 to 200, incl	1000	895	12	40	302	388	Note 2
		over 200 to 240, incl	1000	895	12	40	311	388	Note 4
	2	to 180, incl	1070	965	11	40	311	401	Note 2
		over 180 to 240, incl	1070	965	11	40	321	415	Note 4
	1	to 150, incl	1140	1035	10	35	321	415	Note 3
		over 150 to 200, incl	1140	1035	10	35	331	429	Note 4
B24V	3	to 100, incl	1000	895	12	40	293	363	Note 1
(4340V Mod.)		over 100 to 200, incl	1000	895	12	40	302	375	Note 2
		over 200 to 240, incl	1000	895	12	40	311	388	Note 3
	2	to 100, incl	1070	965	11	40	311	388	Note 2
		over 100 to 200, incl	1070	965	11	40	311	401	Note 3
		over 200 to 280, incl	1070	965	11	40	321	415	Note 4
	1	to 100, incl	1140	1035	10	35	321	415	Note 3
		over 100 to 200, incl	1140	1035	10	35	331	429	Note 4
		over 200 to 280, incl	1140	1035	10	35	331	444	Note 4

TABLE 3 Permissible Variation in Diameter of Rolled Bars[A]

Specified Diameter, in. [mm]	Size Tolerance				Out-of-Round	
	Over		Under			
	in.	mm	in.	mm	in.	mm
1 to 1⅛ [25 to 29], incl	0.010	0.25	0.010	0.25	0.015	0.38
Over 1⅛ to 1¼ [29 to 32], incl	0.011	0.28	0.011	0.28	0.016	0.41
Over 1¼ to 1⅜ [32 to 35], incl	0.012	0.30	0.012	0.30	0.018	0.46
Over 1⅜ to 1½ [35 to 38], incl	0.014	0.36	0.014	0.36	0.021	0.53
Over 1½ to 2 [38 to 50], incl	1⁄64	0.4	1⁄64	0.4	0.023	0.58
Over 2 to 2½ [50 to 65], incl	1⁄32	0.8	0		0.023	0.58
Over 2½ to 3½ [65 to 90], incl	3⁄64	1.2	0		0.035	0.89
Over 3½ to 4½ [90 to 115], incl	1⁄16	1.6	0		0.046	1.17
Over 4½ to 5½ [115 to 140], incl	5⁄64	1.9	0		0.058	1.47
Over 5½ to 6½ [140 to 165], incl	⅛	3.2	0		0.070	1.78
Over 6½ to 8¼ [165 to 210], incl	5⁄32	3.7	0		0.085	2.16
Over 8¼ to 9½ [210 to 240], incl	3⁄16	4.8	0		0.100	2.54

[A] Consult the manufacturer on forged bars, cold-finished bars, bored bars, seamless tubes, and forged hollows.

11. Dimensions and Tolerances

11.1 *Permissible Tolerances for Straightness*:

11.1.1 Annealed material shall have an out-of-straightness tolerance of ⅛ in. in any 5 ft or ⅛ × (number of feet of length/5) in. [2mm/m].

11.1.2 Quenched, tempered and stress-relieved material shall have an out-of-straightness tolerance of ¼ in. in any 5 ft or ¼ × (number of feet of length/5) in. [4 mm/m].

11.2 Unless otherwise specified, headed bolts shall be semi-finished, hexagon in shape, and in accordance with the dimensions of ANSI B 18.2.1. Unless otherwise specified, nuts shall be hexagonal in shape, and in accordance with the dimensions of ANSI B 18.2.2. Unless otherwise specified, the ANSI Standard heavy bolt and nut series shall be used. If socket head fasteners are required, the dimensions shall be in accordance with ANSI B 18.3, as specified by the purchaser.

11.3 All bolts, stud bolts and accompanying nuts, unless otherwise specified, shall be threaded in accordance with ANSI B 1.1, Class 2A or 2B fit.

12. Workmanship, Finish, and Appearance

12.1 The material shall be uniform in quality and free of defects that would be detrimental to the intended service. If magnetic particle inspection for such defects is desired, Supplementary Requirement S6 should be specified.

12.2 *Surface Quality*—Material shall be free of seams, laps, cracks, or other defects that are not removable within the machining cleanup allowance specified in Table 4.

13. Surface Condition

13.1 Material shall be cleaned and furnished in the scale-free condition.

14. Number of Tests

14.1 *Mechanical Tests on Quenched and Tempered Material*:

14.1.1 One test coupon shall be removed from each end of one bar, one seamless tube, or one bored bar or from each of two forged hollows from each size of each heat in each tempering charge, or each 10 000 lb [4540 kg], whichever is less. One tension test and one impact test consisting of three Charpy V-notch specimens shall be taken from each test coupon. For testing in accordance with 16.1.1, two tests shall be obtained from two representative production pieces from each size of each heat in each tempering charge or each 10 000 lb [4540 kg], whichever is less.

TABLE 4 Rolled Bars[A]—Permissible Grinding Depth for Removal of Surface Defects

Diameter, in. [mm]	Minimum Stock Removal Per Side	
	in.	mm
1 to 1⅛ [25 to 29], incl	0.025	0.64
Over 1⅛ to 1¼ [29 to 32], incl	0.028	0.71
Over 1¼ to 1⅜ [32 to 35], incl	0.030	0.76
Over 1⅜ to 1½ [35 to 38], incl	0.033	0.84
Over 1½ to 2 [38 to 50], incl	0.042	1.07
Over 2 to 2½ [50 to 65], incl	0.052	1.32
Over 2½ to 3½ [65 to 90], incl	0.072	1.83
Over 3½ to 4½ [90 to 115], incl	0.090	2.29
Over 4½ to 5½ [115 to 140], incl	0.110	2.79
Over 5½ to 6½ [140 to 165], incl	0.125	3.18
Over 6½ to 8¼ [165 to 210], incl	0.155	3.94
Over 8¼ to 9½ [210 to 240], incl	0.203	5.16

[A] Consult the manufacturer on forged bars, cold-finished bars, bored bars, seamless tubes, and forged hollows.

14.1.2 *Hardness Test*:

14.1.2.1 Bars 2 in. [50 mm] and over and all seamless tubes or bored bars shall be tested near each end of each mill-treated length. Each forged hollow with thickness 2 in. [50 mm] or over shall be tested on the surface.

14.1.2.2 Bars under 2 in. [50 mm] shall be tested near each end of not less than 10 % of the bars. Forged hollows less than 2 in. [50 mm] thick shall be tested on the surface of not less than 10 % of the forgings.

14.2 *Hardness Tests of Annealed Material*:

14.2.1 Hardness tests shall be made on the annealed bars to assure compliance with 10.2.

15. Retests

15.1 If the results of the mechanical tests of any test lot do not conform to the specified requirements, the manufacturer shall reject the lot or he may retreat such a lot not more than twice. After the lot is retreated, all of the tests specified in 14 shall be repeated, and all shall conform to the specified requirements.

16. Test Specimens and Methods of Testing

16.1 A discard equivalent to the diameter of the bar when heat treated as a solid or a discard equivalent to the wall thickness when heat treated as a seamless tube, bored bar, or hollow forging shall be taken prior to removal of test coupons.

16.1.1 When production pieces are not of sufficient length to permit removal of test coupons in accordance with 16.1, the mid-length of the specimens shall be at the mid-length of the production pieces selected for destruction to provide test coupon material. The production pieces selected for test shall be identical with respect to the quenched contour and size except for length which shall equal or exceed the length of the represented production pieces.

16.2 Tension and impact specimens from bolting materials with cross sections of 1½ in. [38 mm] or less shall be taken so that their longitudinal axis is on a line representing the center of the diameter or thickness.

16.3 Tension test specimens from bolting materials with cross sections exceeding 1½ in. [38 mm] shall be taken so that their longitudinal axis is midway between mid-thickness and surface.

16.4 Impact specimens from bolting materials with cross sections exceeding 1½ in. [38 mm] shall be taken so that their longitudinal axis is midway between mid-thickness and surface or 1 in. [25 mm] below the surface plus the machining allowance per side, whichever is the lesser.

17. Certification

17.1 When requested in the purchaser's order, a test report shall be furnished to the purchaser to indicate the specification, grade, and the test results required by this specification plus any other tests which may be specified in writing by the purchaser. The specification designation included on the test reports shall include year date, and revision letter, if any.

18. Product Marking

18.1 Bars under 2 in. [50 mm] in diameter shall be bundled and tagged with the specification, grade, and mill heat number. The specification number marked on the tag need not include specification year date and revision number.

18.2 Bars 2 in. [50 mm] and over in diameter and all seamless tubes and bored bars shall be die-stamped with the mill heat number and grade on one surface.

18.3 Each hollow forging shall be die-stamped with the heat number or heat symbol code and grade.

18.4 Grade and manufacturer's identification symbols shall be applied to one end of studs ⅜ in. [10 mm] in diameter and larger and to the heads of bolts ¼ in. [6 mm] in diameter and larger. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's symbol marked on the other end.)

18.5 For purposes of identification marking, the manufacturer is considered the organization that certifies the bolting material was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

18.6 *Bar Coding*—In addition to the requirements in 18.1-18.5, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG B-5 02.00. If used on small items, the bar code may be applied to the box or a substantially applied tag.

19. Keywords

19.1 bolts—steel; chromium-molybdenum alloy steel; chromium-molybdenum-vanadium alloy steel; chromium-nickel-molybdenum-vanadium alloy steel; fasteners—steel; nickel-chromium-molybdenum alloy steel; nuclear applications; nuts—steel; steel bars—alloy; steel bolting material; tubes—extruded seamless; washers—steel

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order, in which event the tests shall be made at the mill at the purchaser's expense unless otherwise agreed upon.

S1. Product Analysis

S1.1 Product analysis shall be made on each bar, seamless tube, bored bar, or the parent bar from which forged hollows are made. Individual pieces failing to conform to Table 1 shall be rejected.

S2. Macroetch Test

S2.1 The material shall be macroetch tested and shall meet the quality and cleanliness requirements as specified by the purchaser. The macroetch examination may be made on representative billets from which the material will be produced or it may be made on samples cut from the ends of the bars, seamless tubes, bored bars, or forged hollows. The samples shall be prepared in accordance with the procedure described in Method E 381.

NOTE S2.1—The quality and cleanliness may be specified by the purchaser as equal to or better than that indicated by a designated letter and plate number of Military Standard—430 (latest revision).

S3. Ultrasonic Test

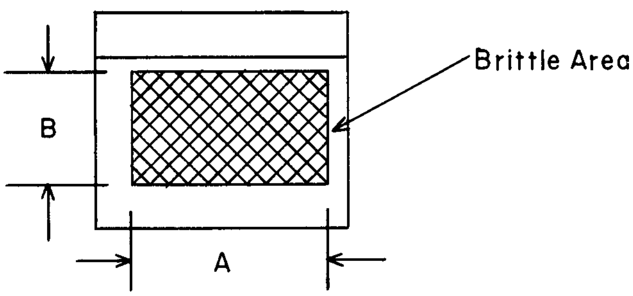
S3.1 Each length shall be ultrasonically inspected in a manner agreeable to the purchaser and supplier.

S4. Demonstration of Capability

S4.1 When annealed material is ordered to 6.1, a sample piece at least 3 *D* long of a representative bar shall be heat treated in accordance with 6.2 and 6.3. Mechanical test samples taken as required by Section 16 shall meet the requirements of 8.2 and 10.2.

S5. Fracture Transition Temperature

S5.1 The fracture transition temperature for a 50 % fibrous (ductile shear) fracture shall be determined. The procedure for determination of the fracture transition temperature shall be to prepare four sets (three to a set) of Charpy V-notch specimens in accordance with Section 16. One set of three specimens shall be tested at approximately 70 °F [20 °C]. The absorbed energy in foot-pounds shall be recorded and the percent of fibrous fracture determined from Table S5.1 and Fig. S5.1. The other three sets shall be tested at successively lower or higher temperatures to bracket the temperature where the material will exhibit a 50 % fibrous fracture. The results of all test data are to be reported to the purchaser.



Measure Dimensions *A* and *B* to the nearest ½ mm.

FIG. S5.1 Calculation of Percent Fibrous Area

S6. Magnetic Particle Inspection

S6.1 Material may be supplied to cleanliness requirements by agreement between the purchaser and supplier. The cleanliness shall be determined by the magnetic particle method described in the latest issue of Practice E 45.

NOTE S6.1—The material shall have the minimum stock removal specified in Table S6.1 prior to magnetic particle inspection.

S7. Elevated Temperature Test

S7.1 Three Charpy V-notch specimens shall be tested at 212 °F [100 °C] to determine the "upper shelf" fracture energy of the material. No specimen thus tested shall break at an energy less than 30 ft·lbf [41 J] .

TABLE S6.1 Rolled Bars[A]—Stock Removal for Magnetic Particle Inspection

Diameter, in. [mm]	Minimum Stock Removal Per Side	
	in.	mm
1 to 1½ [25 to 38], incl	0.075	1.90
Over 1½ to 2 [38 to 50], incl	0.090	2.29
Over 2 to 2½ [50 to 65], incl	0.125	3.18
Over 2½ to 3½ [65 to 90], incl	0.156	3.96
Over 3½ to 4½ [90 to 115], incl	0.187	4.75
Over 4½ to 6 [115 to 155], incl	0.250	6.35
Over 6 to 10 [155 to 255], incl	0.312	7.92

[A] Consult the manufacturer on forged bars, cold-finished bars, bored bars, seamless tubes, and forged hollows.

S8. Alternative Fracture Toughness Requirement

S8.1 The fracture toughness requirements (Charpy impact test) for material of the ASME Boiler and Pressure Vessel Code, Section III, Subarticle NB 2300, shall be used instead of the Charpy impact test requirement specified in Table 2.

TABLE S5.1 Percent Fibrous Fracture[A]
Dimension *A* Width, mm

	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10
Dimension *B* Height, mm																		
1.0	98	98	97	96	96	95	94	94	93	93	92	91	91	90	89	89	88	87
1.5	97	96	95	94	93	93	92	91	90	89	88	87	86	85	85	83	82	81
2.0	96	95	94	93	91	90	89	88	86	85	84	82	81	80	79	78	76	75
2.5	95	94	92	91	89	87	86	84	83	81	80	79	76	75	73	72	70	69
3.0	94	93	91	90	87	85	83	81	79	78	76	74	72	70	68	66	64	63
3.5	93	91	89	87	85	83	80	78	75	74	72	69	67	65	63	61	58	56
4.0	93	90	87	85	83	80	78	75	72	70	68	65	62	60	57	55	52	50
4.5	92	89	86	83	80	78	75	72	69	66	63	61	58	55	52	49	46	43
5.0	91	88	84	81	78	75	72	69	66	63	59	56	53	50	48	44	40	38
5.5	90	86	83	79	75	72	69	66	63	59	55	52	48	45	42	38	35	31
6.0	89	85	81	78	74	70	66	63	59	55	51	47	44	40	36	33	29	25
6.5	88	84	80	76	72	68	63	59	55	51	47	43	40	35	31	27	23	19
7.0	87	82	79	74	69	65	61	56	52	47	43	39	34	30	26	21	16	12
7.5	86	81	76	72	67	62	58	53	48	44	40	34	30	25	23	16	11	6
8.0	85	80	75	70	65	70	55	50	45	40	35	30	25	20	15	10	5	0

[A] See Fig. S5.1.

S9. Marking

S9.1 Grade and manufacturer's identification symbols shall be applied to one end of the studs and to the heads of bolts of all sizes. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end). For bolts and studs smaller than ¼ in. [6 mm] in diameter and for ¼-in. [6 mm] studs requiring more than a total of three symbols, the marking shall be a matter of agreement between the purchaser and manufacturer.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 540/A 540M – 05, that may impact the use of this specification. (Approved March 1, 2006)

(*1*) Revised Section 3 and added new Section 4.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 540/A 540M – 04, that may impact the use of this specification. (Approved March 1, 2005)

(*1*) Revised Table 2 metric values and 11.1.1 and 11.1.2.

(*2*) Corrected reference in 14.1.1 from 16.2.1 to 16.1.1.

Designation: A 530/A 530M – 04a

Standard Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe[1]

This standard is issued under the fixed designation A 530/A 530M; 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*

1.1 This specification[2] covers a group of requirements which, with the exceptions of Section 5.3, Section 13, Section 20, and Section 21, are mandatory requirements to the ASTM pipe product specifications noted below unless the product specification specifies different requirements, in which case the requirement of the product specification shall prevail.

1.2 Sections 5.3 or 20 are mandatory if the product specification has a requirement for product analysis or flattening tests.

1.3 Section 21 is mandatory if the product specification has a hydrostatic test requirement without defining the test parameters.

1.4 Section 13 is for information only.

1.5 In case of conflict between a requirement of the product specification and a requirement of this general requirement specification, only the requirement of the product specification need be satisfied.

Title of Specification	ASTM Designation[A]
Seamless Carbon Steel Pipe for High-Temperature Service	A 106
Metal-Arc-Welded Steel Pipe for Use With High-Pressure Transmission Systems	A 381
Centrifugally Cast Ferritic Alloy Steel Pipe for High-Temperature Service	A 426
Centrifugally Cast Austenitic Steel Pipe for High-Temperature Service	A 451
Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures	A 524
Centrifugally Cast Iron-Chromium-Nickel High-Alloy Tubing for Pressure Application at High Temperatures	A 608
Centrifugally Cast Carbon Steel Pipe for High-Temperature Service	A 660
Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures	A 671
Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures	A 672
Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures	A 691
Centrifugally Cast Ferritic/Austenitic Stainless Steel Pipe for Corrosive Environments	A 872

[A] These designations refer to the latest issue of the respective specifications.

1.6 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 (SI) of the product 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]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

D 3951 Practice for Commercial Packaging

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *ANSI Standards:*

B 36.10 Welded and Seamless Wrought Steel Pipe[4]

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Oct. 1, 2004. Published October 2004. Originally approved in 1965. Last previous edition approved in 2004 as A 530/A 530M – 04.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-530 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 National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

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

B 36.19[4] Stainless Steel Pipe

2.3 *Military Standards:*

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[5]

MIL-STD-271 Nondestructive Testing Requirements for Metals[5]

MIL-STD-792 Identification Marking Requirements for Special Purpose Components[5]

2.4 *Federal Standards:*

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products[5]

2.5 *Steel Structures Painting Council:*

SSPC-SP 6 Surface Preparation Specification No. 6 Commercial Blast Cleaning[6]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *remelted heat*, *n*—in secondary melting, all of the ingots remelted from a single primary heat.

3.1.2 *jointer*, *n*—a length of pipe created by welding two or more shorter lengths of pipe, end-to-end.

3.1.3 *thin-wall pipe*, *n*—a pipe having a wall thickness of 3 % or less of the outside diameter.

3.2 *Other defined terms*—The definitions in Test Methods and Definitions A 370, Test Methods, Practices, and Terminology A 751, and Terminology A 941 are applicable to this specification and to those listed in 1.5.

4. Process

4.1 The steel shall be made from any process.

4.2 If a specific type of melting is required by the purchaser, it shall be stated on the purchase order.

4.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, using electroslag remelting or vacuum remelting.

4.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

5. Chemical Composition

5.1 *Chemical Analysis*—Samples for chemical analysis and method of analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

5.2 *Heat Analysis*—If the heat analysis reported by the steel producer is not sufficiently complete for conformance with the heat analysis requirements of the applicable product specification to be fully assessed, the manufacturer may complete the assessment of conformance with such heat analysis requirements by using a product analysis for the specified elements that were not reported by the steel producer, provided that product analysis tolerances are not applied and the heat analysis is not altered.

5.2.1 For stainless steels ordered under product specifications referencing this specification of general requirements, the steel shall not contain an unspecified element, other than nitrogen, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation in a table of chemical requirements within any specification listed within the scope as being covered by this specification.

5.3 *Product Analysis*—Product analysis requirements and options, if any, are contained in the product specification.

6. Mechanical Requirements

6.1 *Method of Mechanical Tests*—The specimens and the mechanical tests required shall be in accordance with Test Methods and Definitions A 370, especially Annex A2 thereof.

6.2 Specimens shall be tested at room temperature.

6.3 Small or subsize specimens as described in Test Methods and Definitions A 370 may be used only when there is insufficient material to prepare one of the standard specimens. When using small or subsize specimens, the largest one possible shall be used.

7. Tensile Requirements

7.1 The material shall conform to the requirements as to tensile properties prescribed in the individual specifications.

7.2 The yield strength corresponding to a permanent offset of 0.2 % of the gage length or to a total extension of 0.5 % of the gage length under load shall be determined.

7.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than ¾ in. [19.0 mm] from the center of the gage length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

8. Permissible Variation in Weight

8.1 The weight of any length of pipe NPS 12 and under shall not vary more than 10 % over or 3.5 % under that specified. For sizes over NPS 12, the weight of any length of pipe shall not vary more than 10 % over or 5 % under that specified. Unless otherwise specified, pipe of NPS 4 and smaller may be weighed in convenient lots; pipe in sizes larger than NPS 4 shall be weighed separately.

9. Permissible Variations in Wall Thickness

9.1 *Seamless and Welded (no filler metal added)*—The minimum wall thickness at any point shall be within the tolerances specified in Table 1 , except that for welded pipe the weld area shall not be limited by the over tolerance. The minimum wall thickness on inspection for – 12.5 % is shown in Table X1.1.

9.2 *Forged and Bored*—The wall thickness shall not vary over that specified by more than ⅛ in. [3.2 mm]. There shall be no variation under the specified wall thickness.

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[6] Available from Steel Structures Painting Council, 4400 Fifth Ave., Pittsburgh, PA 15213.

TABLE 1 Permissible Variations in Wall Thickness

NPS Designator	Tolerance, % from Nominal	
	Over	Under
⅛ to 2½ , incl., all t/D[A,B] ratios	20.0	12.5
3 to 18 incl., t/D up to 5 % incl.	22.5	12.5
3 to 18 incl., t/D > 5 %	15.0	12.5
20 and larger, welded, all t/D ratios	17.5	12.5
20 and larger, seamless, t/D up to 5 % incl.	22.5	12.5
20 and larger, seamless, t/D > 5 %	15.0	12.5

[A] t = Nominal wall thickness.
[B] D = Ordered outside diameter.

9.3 *Cast*—The wall thickness shall not vary over that specified by more than 1⁄16 in. [1.6 mm]. There shall be no variation under the specified wall thickness.

10. Permissible Variations in Inside Diameter

10.1 *Forged and Bored, and Cast*—The inside diameter shall not vary under that specified by more than 1⁄16 in. [1.6 mm]. There shall be no variation over the specified inside diameter.

11. Permissible Variations in Outside Diameter

11.1 Variations in outside diameter, unless otherwise specified, shall not exceed the limits prescribed in Table 2. The tolerances on outside diameter include ovality except as provided for in 11.2

11.2 Thin-wall pipe usually develops significant ovality (out-of-roundness) during final annealing, straightening, or both. The diameter tolerances of Table 2 are not sufficient to provide for additional ovality expected in thin-wall pipe and are applicable only to the mean of the extreme (maximum and minimum) outside diameter readings in any one cross-section. However, for thin-wall pipe the difference in extreme outside diameter readings (ovality) in any one cross-section shall not exceed 1.5 % of the specified outside diameter.

12. Permissible Variations in Length

12.1 *Seamless and Welded (no filler metal added)*—If definite cut lengths are ordered, no length of pipe shall be under the length specified and not more than ¼ in. [6 mm] over that specified.

12.2 *Forged and Bored, Cast, and Cast Cold-Wrought*—If definite cut lengths are ordered, no length of pipe shall be under the length specified and not more than ⅛ in. [3 mm] over that specified.

TABLE 2 Permissible Variations in Outside Diameter

NPS Designator	Permissible Variations In Outside Diameter			
	Over		Under	
	in.	mm	in.	mm
⅛ to 1½ , incl	1⁄64 (0.015)	0.4	1⁄32 (0.031)	0.8
Over 1½ to 4, incl	1⁄32 (0.031)	0.8	1⁄32 (0.031)	0.8
Over 4 to 8, incl	1⁄16 (0.062)	1.6	1⁄32 (0.031)	0.8
Over 8 to 18, incl	3⁄32 (0.093)	2.4	1⁄32 (0.031)	0.8
Over 18 to 26, incl	⅛ (0.125)	3.2	1⁄32 (0.031)	0.8
Over 26 to 34, incl	5⁄32 (0.156)	4.0	1⁄32 (0.031)	0.8
Over 34	3⁄16 (0.187)	4.8	1⁄32 (0.031)	0.8

12.3 For pipe ordered to random lengths, the lengths and variations shall be agreed upon between the manufacturer and purchaser.

12.4 No jointers are permitted unless otherwise agreed upon.

13. Standard Weight

13.1 A system of standard pipe sizes has been approved by the American National Standards Institute as ANSI B 36.10 and B 36.19. These standard sizes do not prohibit the production and use of other sizes of pipe produced to the various specifications referenced to this Specification.

13.2 For nonstandard sizes of pipe, the calculated weight per foot, shall be determined from the following equation:

$$W = C(D - t)t \tag{1}$$

where:
C = 10.69 [0.0246615],
W = weight, lb/ft [kg/m],
D = specified or calculated (from specified inside diameter and wall thickness) outside diameter, in. [mm], and
t = specified wall thickness, in. (to 3 decimal places) [mm to 2 decimal places].

NOTE 2—The weights given in the American National Standards and the calculated weights given by Eq 1 are based on the weights for carbon steel pipe. The weight of pipe made of ferritic stainless steels may be about 5 % less, and that made of austenitic stainless steel about 2 % greater than the values given.

14. Ends

14.1 Unless otherwise specified, the pipe shall be furnished with plain ends. All burrs at the ends of the pipe shall be removed.

15. Straightness

15.1 The finished pipe shall be reasonably straight.

15.2 For metal-arc welded pipe, the maximum deviation from a 10-ft [3.0-m] straightedge placed so that both ends are in contact with the pipe shall be ⅛ in. [3.2 mm]. For metal-arc welded pipe with lengths shorter than 10 ft [3.0 m], this maximum deviation shall be pro-rated with respect to the ratio of the actual length to 10 ft [3.0 m].

16. Repair by Welding

16.1 Repair by welding of defects in seamless pipe (including centrifugally cast and forged and bored) and of plate defects in welded pipe and, when specifically stated by the product specification weld seam defects in welded pipe, shall be permitted subject to the approval of the purchaser and with the further understanding that the composition of the deposited filler metal shall be suitable for the composition being welded. Defects shall be thoroughly chipped or ground out before welding and each repaired length shall be reheat treated or stress relieved as required by the applicable specification. Each length of repaired pipe shall be tested hydrostatically as required by the product specification.

16.2 Repair welding shall be performed using procedures and welders or welding operators that have been qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

17. Retests

17.1 If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional lengths of pipe of double the original number from the same group or lot, each of which shall conform to the requirements specified. Only one retest of any group or lot will be permitted. Nonconformance will be cause for the rejection of the group or lot.

17.2 Any individual length of pipe that meets the test requirements is acceptable. Individual lengths that do not conform to the test requirements may be resubmitted for test provided the reason for nonconformance is established and the nonconforming portion removed.

18. Retreatment

18.1 If individual lengths of pipe selected to represent any group or lot fail to conform to the test requirements, the group or lot represented may be reheat treated and resubmitted for test. The manufacturer may reheat treat the pipe, but not more than twice, except with the approval of the purchaser on the basis of satisfactory metallurgical evidence that the cause of failure of the test is curable and the quality of the material is satisfactory.

19. Test Specimens

19.1 Test specimens shall be taken from the ends of finished pipe prior to any forming operations, or being cut to length. They shall be smooth on the ends and free from burrs and flaws, except for specimens for the flattening test when made from crop ends.

19.2 Specimens cut either longitudinally or transversely shall be acceptable for the tension test.

19.3 If any test specimen shows flaws or defective machining, the specimen may be discarded and another substituted.

20. Flattening Test Requirements

20.1 *Seamless and Centrifugally Cast Pipe*—A section of pipe not less than 2½ in. [63 mm] in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, no cracks or breaks on the inside, outside, or end surfaces, except as provided for in 20.3.4, shall occur until the distance between the plates is less than the value of H calculated as follows:

$$H = (1 + e)t/(e + t/D) \tag{2}$$

where:

H = distance between flattening plates, in. [mm],
t = specified wall thickness, in. [mm],
D = specified or calculated (from the specified inside diameter and wall thickness) outside diameter, in. [mm], and
e = deformation per unit length (constant for a given grade of steel; 0.07 for medium carbon steel (maximum specified carbon 0.19 % or greater), 0.08 for ferritic alloy steel, 0.09 for austenitic steel, and 0.09 for low-carbon steel (maximum specified carbon 0.18 % or less)).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet.

20.2 *Welded Pipe*—A section of welded pipe not less than 4 in. [100 mm] in length shall be flattened cold between parallel plates in two steps. The weld shall be placed 90° from the direction of the applied force (at the point of maximum bending). During the first step, which is a test for ductility, no cracks or breaks on the inside or outside surfaces, except as provided for in 20.3.4, shall occur until the distance between the plates is less than the value of H calculated by Eq 2. During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet.

20.3 *Seamless, Centrifugally Cast, and Welded Pipe*:

20.3.1 Evidence of laminated or defective material or weld that is revealed during the entire flattening test shall be cause for rejection.

20.3.2 Surface imperfections not evident in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

20.3.3 Superficial ruptures resulting from surface imperfections shall not be a cause for rejection.

20.3.4 When low D-to- t ratio tubular products are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D to t ratio is less than 10.

21. Hydrostatic Test Requirements

21.1 Except as provided in 21.2 and 21.3, each length of pipe shall be tested by the manufacturer to a hydrostatic pressure which will produce in the pipe wall a stress not less that 60 % of the minimum specified yield strength for carbon and ferritic alloy steel pipe, or 50 % of the specified minimum yield strength for austenitic alloy steel pipe. The test pressure or stress shall be determined by the following equation:

$$P = 2St/D \text{ or } S = PD/2t \tag{3}$$

where:

P = hydrostatic test pressure in psi or MPa,
S = pipe wall stress in psi or MPa,
t = specified nominal wall thickness, nominal wall thickness corresponding to specified ANSI schedule number, or 1.143 times the specified minimal wall thickness, in. [mm], and
D = specified outside diameter, outside diameter corresponding to specified ANSI pipe size, or outside diameter calculated by adding $2t$ (as defined above) to the specified inside diameter, in. [mm].

21.1.1 The hydrostatic test pressure determined by the equation shall be rounded to the nearest 50 psi [0.5 MPa] for pressures below 1000 psi [7 MPa], and to the nearest 100 psi [1 MPa] for pressures 1000 psi [7 MPa] and above. The hydrostatic test may be performed prior to cutting to final length, or prior to upsetting, swaging, expanding, bending, or other forming operations.

21.2 Regardless of pipe-wall stress-level determined by Eq 3, the minimum hydrostatic test pressure required to satisfy these requirements need not exceed 2500 psi [17.0 MPa] for outside diameters (see *D* in 21.1) of 3.5 in. [88.9 mm] or less, nor 2800 psi [19.0 MPa] for outside diameters over 3.5 in. [88.9 mm]. This does not prohibit testing at higher pressures at the manufacturer's option or as provided in 21.3.

21.3 With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements of 21.2 or 21.1, or both, may be stated on the order.

21.4 The test pressure shall be held for a minimum of 5 s, without resultant leakage through the pipe wall. For welded pipe, the test pressure shall be held for a time sufficient to permit the inspector to examine the entire length of the welded seam.

21.5 The hydrostatic test may not be capable of inspecting the end portion of the pipe. The length of pipe that cannot be tested shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

22. Certified Test Report

22.1 When specified in the purchase order or contract, the producer or supplier shall furnish a certified test report certifying that the material was manufactured, sampled, tested and inspected in accordance with the specification, including year date, the supplementary requirements, and any other requirements designated in the purchase order or contract, and that the results met the requirements of that specification, the supplementary requirements and the other requirements. A signature or notarization is not required on the certified test report, but the document shall be dated and shall clearly identify the organization submitting the report.

NOTE 3—Notwithstanding the absence of a signature or notarization, the organization submitting the report is responsible for the contents of the report.

22.2 In addition, the certified test report shall include the following information and test results, when applicable:

22.2.1 Heat Number,

22.2.2 Heat Analysis,

22.2.3 Product Analysis, if specified or required,

22.2.4 Tensile Properties,

22.2.5 Width of the gage length, when longitudinal strip tension test specimens are used,

22.2.6 Bend Test acceptable,

22.2.7 Flattening Test acceptable,

22.2.8 Hydrostatic Test pressure

22.2.9 Non-destructive Electric Test method,

22.2.10 Impact Test results, and

22.2.11 Other test results or information required to be reported by the product specification.

22.3 Test results or information required to be reported by supplementary requirements, or other requirements designated in the purchase order or contract shall be reported, but may be reported in a separate document.

22.4 The certified test report shall include a statement of explanation for the letter added to the specification number marked on the tubes (see 25.5) when all of the requirements of the specification have not been completed. The purchaser must certify that all requirements of the specification have been completed before removal of the letter (that is, X, Y, or Z).

22.5 When certification is required for material that has not been hydrostatically tested, the certificate of test shall state "Not hydrostatically tested'', and the letters "NH'' shall be appended to the product specification number, material grade and class shown on the certificate.

22.6 A test report, certificate of compliance, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

23. Inspection

23.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with operation of the works.

24. Rejection

24.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

24.2 Pipe that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the suitability of the pipe. Disposition of such pipe shall be a matter for agreement.

25. Product Marking

25.1 Each length of pipe shall be legibly marked with the manufacturer's name or brand, the specification number (year of issue not required) and grade. Marking shall begin approximately 12 in. [300 mm] from the end of each length of pipe. For pipe less than NPS 2 and pipe under 3 ft [1 m] in length, the required information may be marked on a tag securely attached to the bundle or box in which the pipes are shipped.

25.2 When pipe marked as specified is rejected, the ASTM designation shall be cancelled.

25.3 For austenitic steel pipe, the marking paint or ink shall not contain any harmful metal, or metal salts, such as zinc, lead, or copper, which cause corrosive attack on heating.

25.4 Pipes which have been weld repaired in accordance with 16.1 shall be marked *WR*.

25.5 When it is specified that certain requirements of a specification adopted by the ASME Boiler and Pressure Vessel

Committee are to be completed by the purchaser upon receipt of the material, the manufacturer shall indicate that all requirements of the specification have not been completed by a letter such as *X*, *Y*, or *Z*, immediately following the specification number. This letter may be removed after completion of all requirements in accordance with the specification. An explanation of specification requirements to be completed is provided in 24.1.

25.6 *Bar Coding*—In addition to the requirements in 25.1, 25.2, 25.3, 25.4 and 25.5, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

26. Packaging, Marking, and Loading

26.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with the procedures of Practices A 700.

27. Government Procurement

27.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order for agencies of the U.S. Government where scale free pipe is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

27.1.1 Pipe shall be ordered to nominal pipe size (NPS) and schedule. Nominal pipe shall be as specified in ANSI B 36.10.

27.1.2 *Responsibility for Inspection*— Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility for ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept the material. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to the prescribed requirements.

27.1.3 *Sampling for Flattening and Flaring Test and for Visual and Dimensional Examination*—Minimum sampling for flattening and flaring tests and visual and dimensional examination shall be as follows:

Lot Size (pieces per lot)	Sample Size
2 to 8	Entire lot
9 to 90	8
91 to 150	12
151 to 280	19
281 to 500	21
501 to 1200	27
1201 to 3200	35
3201 to 10 000	38
10 001 to 35 000	46

In all cases, the acceptance number is zero and the rejection number is one. Rejected lots may be screened and resubmitted for visual and dimensional examination. All defective items shall be replaced with acceptable items prior to lot acceptance.

27.1.4 *Sampling for Chemical Analysis*— One sample for chemical analysis shall be selected from each of two pipes chosen from each lot. A lot shall be all material poured from one heat.

27.1.5 *Sampling for Tension and Bend Test*— One sample shall be taken from each lot. A lot shall consist of all pipe of the same outside diameter and wall thickness manufactured during an 8-h shift from the same heat of steel, and heat treated under the same conditions of temperature and time in a single charge in a batch type furnace, or heat treated under the same condition in a continuous furnace, and presented for inspection at the same time.

27.1.6 *Hydrostatic and Ultrasonic Tests*— Each pipe shall be tested by the ultrasonic (when specified) and hydrostatic tests.

27.1.7 Pipe shall be free from heavy oxide or scale. The internal surface of hot finished ferritic steel pipe shall be pickled or blast cleaned to a free of scale condition equivalent to the CSa2 visual standard listed in SSPC-SP6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

27.1.8 In addition to the marking in Specification A 450/A 450M, each length of pipe ¼ in. outside diameter and larger shall be marked with the following listed information. Marking shall be in accordance with FED-STD-183 and MIL-STD-792. (*a*) Nominal Pipe Size Schedule and Length (*b*) Heat or lot identification number.

27.1.9 Pipe shall be straight to within the tolerances specified in Table 3.

27.1.10 When specified, each pipe shall be ultrasonically examined in accordance with MIL-STD-271, except that the notch depth in the calibration standard shall be 5 % of the wall

TABLE 3 Straightness Tolerances

Specified OD, in.	Specified wall thickness, in.	Maximum curvature in any 3 ft, in.	Maximum curvature in total length, in.
Up to 5.0, incl.	Over 3 % OD to 0.5, incl.	0.030	0.010 × length, ft
Over 5.0 to 8.0, incl.	Over 4 % OD to 0.75, incl.	0.045	0.015 × length, ft
Over 8.0 to 12.75, incl.	Over 4 % OD to 1.0, incl.	0.060	0.020 × length, ft

thickness or 0.005 in., whichever is greater. Any pipe which produces an indication equal to or greater than 100 % of the indication from the calibration standard shall be rejected.

27.1.11 The pipe shall be free from repair welds, welded joints, laps, laminations, seams, visible cracks, tears, grooves, slivers, pits, and other imperfections detrimental to the pipe as determined by visual and ultrasonic examination, or alternate tests, as specified.

27.1.12 Pipe shall be uniform in quality and condition and have a finish conforming to the best practice for standard quality pipe. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be considered injurious if the imperfections are removable within the tolerances specified for wall thickness or 0.005 in., whichever is greater. The bottom of imperfections shall be visible and the profile shall be rounded and faired-in.

27.1.13 No weld repair by the manufacturer is permitted.

27.1.14 Preservation shall be level A or commercial, and packing shall be level A, B, or commercial, as specified. Level A preservation and level A or B packing shall be in accordance with MIL-STD-163 and commercial preservation and packing shall be in accordance with Practices A 700 or Practice D 3951.

28. Keywords

28.1 alloy steel pipe; carbon steel pipe; general delivery requirements; steel pipe

APPENDIX

(Nonmandatory Information)

X1. TABLE OF MINIMUM WALL THICKNESSES

Table X1.1 displays minimum wall thicknesses.

TABLE X1.1 Minimum Wall Thicknesses on Inspection for Nominal (Average) Pipe Wall Thicknesses

NOTE 1—The following equation, upon which this table is based, may be applied to calculate minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:
t_n = nominal (average) wall thickness, in. [mm], and
t_m = minimum wall thickness, in. [mm].

The wall thickness is expressed to three decimal places, the fourth decimal place being carried forward or dropped, in accordance with the Practice E 29.

NOTE 2—This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)	
in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.068	1.73	0.060	1.52	0.294	7.47	0.257	6.53	0.750	19.05	0.656	16.62
0.088	2.24	0.077	1.96	0.300	7.62	0.262	6.65	0.812	20.62	0.710	18.03
0.091	2.31	0.080	2.03	0.307	7.80	0.269	6.83	0.843	21.41	0.738	18.75
0.095	2.41	0.083	2.11	0.308	7.82	0.270	6.86	0.864	21.95	0.756	19.20
0.113	2.87	0.099	2.51	0.312	7.92	0.273	6.93	0.875	22.22	0.766	19.46
0.119	3.02	0.104	2.64	0.318	8.08	0.278	7.06	0.906	23.01	0.793	20.14
0.125	3.18	0.109	2.77	0.322	8.18	0.282	7.17	0.937	23.80	0.820	20.83
0.126	3.20	0.110	2.79	0.330	8.38	0.289	7.34	0.968	24.59	0.847	21.51
0.133	3.38	0.116	2.95	0.337	8.56	0.295	7.49	1.000	25.40	0.875	22.22
0.140	3.56	0.122	3.10	0.343	8.71	0.300	7.62	1.031	26.19	0.902	22.91
0.145	3.68	0.127	3.23	0.344	8.74	0.301	7.65	1.062	26.97	0.929	23.60
0.147	3.73	0.129	3.28	0.358	9.09	0.313	7.95	1.093	27.76	0.956	24.28
0.154	3.91	0.135	3.43	0.365	9.27	0.319	8.10	1.125	28.57	0.984	24.99
0.156	3.96	0.136	3.45	0.375	9.52	0.328	8.33	1.156	29.36	1.012	25.70
0.179	4.55	0.157	3.99	0.382	9.70	0.334	8.48	1.218	30.94	1.066	27.08
0.187	4.75	0.164	4.17	0.400	10.16	0.350	8.89	1.250	31.75	1.094	27.77
0.188	4.78	0.164	4.17	0.406	10.31	0.355	9.02	1.281	32.54	1.121	28.47
0.191	4.85	0.167	4.24	0.432	10.97	0.378	9.60	1.312	33.32	1.148	29.16
0.200	5.08	0.175	4.44	0.436	11.07	0.382	9.70	1.343	34.11	1.175	29.84
0.203	5.16	0.178	4.52	0.437	11.10	0.382	9.70	1.375	34.92	1.203	30.56
0.216	5.49	0.189	4.80	0.438	11.13	0.383	9.73	1.406	35.71	1.230	31.24
0.218	5.54	0.191	4.85	0.500	12.70	0.438	11.13	1.438	36.52	1.258	31.95
0.219	5.56	0.192	4.88	0.531	13.49	0.465	11.81	1.500	38.10	1.312	33.32
0.226	5.74	0.198	5.03	0.552	14.02	0.483	12.27	1.531	38.89	1.340	34.04
0.237	6.03	0.207	5.23	0.562	14.27	0.492	12.50	1.562	39.67	1.367	34.72
0.250	6.35	0.219	5.56	0.593	15.06	0.519	13.18	1.593	40.46	1.394	35.40
0.258	6.55	0.226	5.74	0.600	15.24	0.525	13.34	1.750	44.45	1.531	38.89
0.276	7.01	0.242	6.15	0.625	15.88	0.547	13.89	1.781	45.24	1.558	39.57
0.277	7.04	0.242	6.15	0.656	16.62	0.573	14.55	1.812	46.02	1.586	40.28
0.279	7.09	0.244	6.20	0.674	17.12	0.590	14.99	1.968	49.99	1.722[A]	43.74
0.280	7.11	0.245	6.22	0.687	17.45	0.601	15.27	2.062	52.38	1.804	45.82
0.281	7.14	0.246	6.25	0.719	18.26	0.629	15.98	2.343	59.51	2.050	52.07

[A] Editorially corrected in October 2000.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 530/A 530M – 04, that may impact the use of this specification. (Approved October 1, 2004)

(*1*) Added 22.6.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 530/A 530M – 03, that may impact the use of this specification. (Approved March 1, 2004)

(*1*) Revised 5.2.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 530/A 530M – 02, that may impact the use of this specification. (Approved September 10, 2003)

(*1*) Added reference to Terminology A 941 in Section 2.

(*2*) Added a Terminology Section (new Section 3), including a definition for "jointer," and renumbered the subsequent sections accordingly.

Standard Specification for Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures[1]

This standard is issued under the fixed designation A 524; 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 seamless carbon steel pipe intended primarily for service at atmospheric and lower temperatures, NPS ⅛ to 26 inclusive, with nominal (average) wall thickness as given in ANSI B36.10. Pipe having other dimensions may be furnished, provided such pipe complies with all other requirements of this specification. Pipe ordered to this specification shall be suitable both for welding, and for bending, flanging, and similar forming operations.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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 The following hazard caveat applies to the test methods portion, Section 16, only. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *American National Standards Institute Standard:*

B36.10 Welded and Seamless Wrought Steel Pipe[4]

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 or number of lengths),

3.1.2 Name of material (seamless carbon steel pipe),

3.1.3 Grade (Table 1 and Table 2),

3.1.4 Manufacture (hot finished or cold drawn),

3.1.5 Size (either nominal wall thickness and weight class or schedule number, or both, or outside diameter and nominal wall thickness, ANSI B36.10),

3.1.6 Length (17),

3.1.7 Optional requirements (Section 8 and Section 11 of Specification A 530/A 530M),

3.1.8 Test report required (Certification Section of Specification A 530/A 530M),

3.1.9 Specification designation,

3.1.10 End use of material, and

3.1.11 Special requirements.

4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

5. Materials and Manufacture

5.1 *Process*:

5.1.1 The steel shall be killed steel made by one or more of the following processes: open-hearth, electric-furnace, or basic-oxygen.

5.1.2 The steel shall be made to fine grain practice.

5.1.3 Steel may be cast in ingots or may be strand cast. When steel of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

5.1.4 Pipe NPS 1½ and under may be either hot finished or cold drawn.

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Oct. 1, 2005. Published November 2005. Originally approved in 1965. Last previous edition approved in 2001 as A 524 – 96 (2001).

[2] For ASME Boiler and Pressure Vessel Code Applications see related Specification SA-524 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 National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

TABLE 1 Chemical Requirements

Element	Grades I and II, Composition, %
Carbon, max	0.21
Manganese	0.90–1.35
Phosphorus, max	0.035
Sulfur, max	0.035
Silicon	0.10–0.40

5.1.5 Unless otherwise specified, pipe NPS 2 and over shall be furnished hot finished. When agreed upon between the manufacturer and purchaser, cold-drawn pipe may be furnished.

5.2 *Heat Treatment*—All hot-finished and cold-drawn pipe shall be reheated to a temperature above 1550 °F (845°C) and followed by cooling in air or in the cooling chamber of a controlled atmosphere furnace.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements prescribed in Table 1.

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified in Section 6. The chemical composition thus determined, or that determined from a product analysis made by the manufacturer, if the latter has not manufactured the steel, shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 6.

8. Product Analysis

8.1 At the request of the purchaser, analyses of two pipes from each lot (Note 2) shall be made by the manufacturer from the finished pipe. The chemical composition thus determined shall conform to the requirements specified in Section 6.

NOTE 2—A lot shall consist of 400 lengths, or fraction thereof, for each size NPS 2 up to but not including NPS 6, and of 200 lengths, or fraction thereof, for each size NPS 6 and over.

8.2 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in 6, analyses shall be made on additional pipe of double the original number from the same lot, each of which shall conform to requirements specified.

9. Physical Properties

9.1 *Tensile Properties*—The material shall conform to the requirements as to tensile properties prescribed in Table 2.

9.2 *Bending Properties*:

9.2.1 For pipe NPS 2 and under, a sufficient length of pipe shall stand being bent cold through 90° around a cylindrical mandrel, the diameter of which is twelve times the nominal diameter of the pipe, without developing cracks. When ordered for close coiling, the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the nominal diameter of the pipe, without failure.

9.2.2 For pipe whose diameter exceeds 25 in. (635 mm) and whose diameter to wall thickness ratio is 7.0 or less, bend test specimens shall be bent at room temperature through 180° without cracking on the outside of the bent portion. The inside diameter of the bend shall be 1 in. (25.4 mm). This test shall be in place of Section 10.

NOTE 3—Diameter to wall thickness ratio = specified outside diameter/nominal wall thickness.
Example: For 28 in. diameter 5.000 in. thick pipe the diameter to wall thickness ratio = 28/5 = 5.6.

10. Flattening Test Requirements

10.1 For pipe over NPS 2, a section of pipe not less than 2½ in. (63.5 mm) in length shall be flattened cold between parallel plates until the opposite walls of the pipe meet. Flattening tests shall be in accordance with Specification A 530/A 530M, except that in the equation used to calculate the *H* value, the following *e* constants shall be used:

0.07 for Grade I
0.08 for Grade II

10.2 When low *D*-to-*t* ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the *D*-to-*t* ratio is less than ten.

11. Hydrostatic Test Requirements

11.1 Each length of pipe shall be subjected to the hydrostatic pressure, except as provided in 11.2.

11.2 When specified in the order, pipe may be furnished without hydrostatic testing and each length so furnished shall include with the mandatory marking the letters "NH."

11.3 When certification is required by the purchaser and the hydrostatic test has been omitted, the certification shall clearly state "Not Hydrostatically Tested," and the specification number and grade designation, as shown on the certification, shall be followed by the letters "NH."

12. Dimensions and Weights

12.1 The dimensions and weights of plain-end pipe are included in ANSI B36.10. Sizes and wall thicknesses most generally available are listed in Appendix X1.

13. Dimensions, Weight, and Permissible Variations

13.1 *Weight*—The weight of any length of pipe shall not vary more than 6.5 % over and 3.5 % under that specified for pipe of Schedule 120 and lighter nor more than 10 % over and 3.5 % under that specified for pipe heavier than Schedule 120. Unless otherwise agreed upon between the manufacturer and purchaser, pipe in sizes NPS 4 and smaller may be weighed in convenient lots; pipe in sizes larger than NPS 4 shall be weighed separately.

13.2 *Diameter*—Variations in outside diameter shall not exceed those specified in Table 3.

13.3 *Thickness*—The minimum wall thickness at any point shall not be more than 12.5 % under the nominal wall thickness specified.

NOTE 4—The minimum wall thickness on inspection is shown in Appendix X1.

TABLE 2 Tensile Requirements

	Wall Thicknesses			
	Grade I, 0.375 in. (9.52 mm) and under		Grade II, greater than 0.375 in. (9.52 mm)	
Tensile strength, psi (MPa)	60 000–85 000 (414–586)		55 000–80 000 (380–550)	
Yield strength, min, psi (MPa)	35 000 (240)		30 000 (205)	
	Longitudinal	Transverse	Longitudinal	Transverse
Elongation in 2 in. or 50 mm, min %:				
Basic minimum elongation for walls 5⁄16 in. (7.9 mm) and over in thickness, strip tests, and for all small sizes tested in full section	30	16.5	35	25
When standard round 2 in. or 50 mm gauge length test specimen is used for strip tests, a deduction for each 1⁄32 in. (0.8 mm) decrease in wall thickness below 5⁄16 in. (7.9 mm) from the basic minimum elongation of the following percentage	22 1.50[A]	12 1.00[A]	28 ...	20 ...

[A] The following table gives the computed minimum values:

Wall Thickness		Elongation in 2 in. or 50 mm, min, %	
		Grade I	
in.	mm	Longitudinal	Transverse
5⁄16 (0.312)	7.94	30.0	16.5
9⁄32 (0.281)	7.14	28.5	15.5
1⁄4 (0.250)	6.35	27.0	14.5
7⁄32 (0.219)	5.56	25.5	. . .
3⁄16 (0.188)	4.76	24.0	. . .
5⁄32 (0.156)	3.97	22.5	. . .
1⁄8 (0.125)	3.18	21.0	. . .
3⁄32 (0.094)	2.38	19.5	. . .
1⁄16 (0.062)	1.59	18.0	. . .

Note—The above table gives the computed minimum elongation values for each 1⁄32-in. (0.79-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
I	transverse	$E = 32t + 6.50$
I	longitudinal	$E = 48t + 15.00$

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

TABLE 3 Variations in Outside Diameter

NPS Designator	Permissible Variations in Outside Diameter, in. (mm)	
	Over	Under
1⁄8 to 1½ , incl	1⁄64 (0.4)	1⁄32 (0.8)
Over 1½ to 4, incl	1⁄32 (0.8)	1⁄32 (0.8)
Over 4 to 8, incl	1⁄16 (1.6)	1⁄32 (0.8)
Over 8 to 18, incl	3⁄32 (2.4)	1⁄32 (0.8)
Over 18	1⁄8 (3.2)	1⁄32 (0.8)

14. Workmanship, Finish, and Appearance

14.1 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 assure compliance with 14.2.

14.2 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:

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

14.2.2 Repaired in accordance with the repair welding provisions of 14.6.

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

14.2.4 Rejected.

14.3 To provide a workmanlike finish and basis for evaluating conformance with 14.2, the pipe manufacturer shall remove by grinding the following noninjurious imperfections:

14.3.1 Mechanical marks, abrasions (Note 5), and pits, any of which imperfections are deeper than 1⁄16 in. (1.58 mm).

Note 5—Marks and abrasions are defined as cable marks, dinges, guide marks, roll marks, ball scratches, scores, die marks, and the like.

14.3.2 Visual imperfections, commonly referred to as scabs, seams, laps, tears, or slivers, found by exploration in accordance with 14.1 to be deeper than 5 % of the nominal wall thickness.

14.4 At the purchaser's discretion, pipe shall be subject to rejection if surface imperfections acceptable under 14.2 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.

14.5 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.

14.5.1 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.

14.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 530/A 530M.

14.7 The finished pipe shall be reasonably straight.

15. Number of Tests and Retests

15.1 One of either of the tests specified in 9.1 shall be made on one length of pipe from each lot (Note 2).

15.2 For pipe NPS 2 and under, the bend test specified in 9.2 shall be made on one pipe from each lot (Note 2). The bend tests specified in 9.2.2 shall be made on one end of each pipe.

15.3 The flattening test specified in 10 shall be made on one length of pipe from each lot (Note 2).

15.4 Retests shall be in accordance with Specification A 530/A 530M and as provided in 15.5 and 15.6.

15.5 If a specimen breaks in an inside or outside surface flaw, a retest shall be allowed.

15.6 Should a crop end of a finished pipe fail in the flattening test, one retest may be made from the broken end.

16. Test Specimens and Methods of Testing

16.1 Specimens cut either longitudinally or transversely shall be acceptable for the tension test.

16.2 Test specimens for the bend test specified in 9.2 and for the flattening tests specified in 10 shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except when made on crop ends.

16.3 Test specimens for the bend test specified in 9.2.2 shall be cut from one end of the pipe and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either ½ by ½ in. (12.7 mm) in section or 1 by ½ in. (25.4 by 12.7 mm) in section with the corners rounded to a radius not over 1⁄16 in. (1.6 mm) and need not exceed 6 in. (152 mm) in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe respectively.

17. Lengths

17.1 Pipe lengths shall be in accordance with the following regular practice:

17.1.1 The lengths required shall be specified in the order, and

17.1.2 No jointers are permitted unless otherwise specified.

17.2 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft (4.9 to 6.7 m), with 5 % 12 to 16 ft (3.7 to 4.9 m), or in double random lengths with a minimum average of 35 ft (10.7 m) and a minimum length of 22 ft with 5 % 16 to 22 ft.

18. Rejection

18.1 Each length of pipe that develops injurious defects during shop working or application operations will be rejected, and the manufacturer shall be notified. No rejections under this or any other specifications shall be marked as specified in 19 for sale under this specification except where such pipe fails to comply with the weight requirements alone, in which case it may be sold under the weight specifications with which it does comply.

19. Product Marking

19.1 In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include the hydrostatic test pressure when tested or the letters "NH" when not tested, the length and schedule number, and on pipe sizes larger than NPS 4 the weight shall be given. Length shall be marked in feet and tenths of a foot, or metres to two decimal places, depending on the units to which the material was ordered, or other marking subject to agreement.

19.2 *Bar Coding*—In addition to the requirements in 19.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

APPENDIX

(Nonmandatory Information)

X1. DIMENSIONS AND WALL THICKNESSES

X1.1 Following are Tables X1.1 and X1.2, cited in the text of this standard.

TABLE X1.1 Table of Minimum Wall Thicknesses on Inspection for Nominal (Average) Pipe Wall Thickness

NOTE 1—The following equation, upon which this table is based, may be applied to calculate minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:
t_n= nominal (average) wall thickness, in. (mm), and
t_m= minimum wall thickness, in. (mm).

NOTE 2—The wall thickness is expressed to three decimal places, the fourth decimal place being carried forward or dropped, in accordance with Practice E 29. This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)		Nominal (Average) Thickness (t_n)		Minimum Thickness on Inspection (t_m)	
in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.068	1.73	0.060	1.52	0.281	7.14	0.246	6.25	0.864	21.94	0.756	19.20
0.083	2.11	0.073	1.85	0.294	7.47	0.257	6.53	0.875	22.22	0.766	19.46
0.088	2.24	0.077	1.96	0.300	7.62	0.262	6.65	0.906	23.01	0.793	20.14
0.091	2.31	0.080	2.03	0.307	7.80	0.269	6.83	0.938	23.82	0.821	20.85
0.095	2.41	0.083	2.11	0.308	7.82	0.270	6.86	0.968	24.59	0.847	21.51
0.109	2.77	0.095	2.41	0.312	7.92	0.273	6.93	1.000	25.40	0.875	22.22
0.113	2.87	0.099	2.51	0.318	8.07	0.278	7.06	1.031	26.19	0.902	22.91
0.119	3.02	0.104	2.64	0.322	8.18	0.282	7.16	1.062	26.97	0.929	23.60
0.125	3.18	0.109	2.77	0.330	8.38	0.289	7.34	1.094	27.79	0.957	24.31
0.126	3.20	0.110	2.79	0.337	8.56	0.295	7.49	1.125	28.58	0.984	24.99
0.133	3.38	0.116	2.95	0.344	8.74	0.301	7.64	1.156	29.36	1.012	25.70
0.140	3.56	0.122	3.10	0.358	9.09	0.313	7.95	1.219	30.96	1.066	27.08
0.141	3.58	0.123	3.12	0.365	9.27	0.319	8.10	1.250	31.75	1.094	27.79
0.145	3.68	0.127	3.23	0.375	9.52	0.328	8.33	1.281	32.54	1.121	28.47
0.147	3.73	0.129	3.28	0.382	9.70	0.334	8.48	1.312	33.32	1.148	29.16
0.154	3.91	0.135	3.43	0.400	10.16	0.350	8.89	1.375	34.92	1.203	30.56
0.156	3.96	0.136	3.45	0.406	10.31	0.355	9.02	1.406	35.71	1.230	31.24
0.172	4.37	0.150	3.81	0.432	10.97	0.378	9.60	1.438	36.53	1.258	31.95
0.179	4.55	0.157	3.99	0.436	11.07	0.382	9.70	1.500	38.10	1.312	33.32
0.188	4.78	0.164	4.17	0.438	11.12	0.383	9.73	1.531	38.89	1.340	34.04
0.191	4.85	0.167	4.24	0.469	11.91	0.410	10.41	1.562	39.67	1.367	34.72
0.200	5.08	0.175	4.44	0.500	12.70	0.438	11.13	1.594	40.49	1.395	35.43
0.203	5.16	0.178	4.52	0.531	13.49	0.465	11.81	1.635	41.53	1.431	36.35
0.210	5.33	0.184	4.67	0.552	14.02	0.483	12.27	1.750	44.45	1.531	38.89
0.216	5.49	0.189	4.80	0.562	14.27	0.492	12.50	1.781	45.24	1.558	39.57
0.218	5.54	0.191	4.85	0.594	15.09	0.520	13.21	1.812	46.02	1.586	40.28
0.219	5.56	0.192	4.88	0.600	15.24	0.525	13.34	1.875	47.62	1.641	41.68
0.226	5.74	0.198	5.03	0.625	15.88	0.547	13.89	1.969	50.01	1.723	43.76
0.237	6.02	0.207	5.26	0.656	16.66	0.574	14.58	2.000	50.80	1.750	44.45
0.250	6.35	0.219	5.56	0.674	17.12	0.590	14.99	2.062	52.37	1.804	45.82
0.258	6.55	0.226	5.74	0.688	17.48	0.602	15.29	2.125	53.98	1.859	47.22
0.276	7.01	0.242	6.15	0.719	18.26	0.629	15.98	2.200	55.88	1.925	48.90
0.277	7.04	0.242	6.15	0.750	19.05	0.656	16.66	2.344	59.54	2.051	52.10
0.279	7.09	0.244	6.19	0.812	20.62	0.710	18.03	2.500	63.50	2.188	55.58
0.280	7.11	0.245	6.22	0.844	21.44	0.739	18.77				

TABLE X1.2 Dimensions, Weights and Test Pressures for Plain End Pipe
(As appears in American National Standard B36.10)

NPS Designator	Wall Thickness	Nominal Weight	Weight Class	Schedule No.	Test Pressure	
					Grade I	Grade II
	in. (mm)	lb/ft (kg/m)	psi (MPa)	psi (MPa)		
⅛	0.068 (1.73)	0.24 (0.36)	std	40	2500 (17.2)	...
	0.095 (2.41)	0.31 (0.46)	XS	80	2500 (17.2)	...
¼	0.088 (2.24)	0.42 (0.63)	std	40	2500 (17.2)	...
	0.119 (3.02)	0.54 (0.80)	XS	80	2500 (17.2)	...
⅜	0.091 (2.31)	0.57 (0.85)	std	40	2500 (17.2)	...
	0.126 (3.20)	0.74 (1.10)	XS	80	2500 (17.2)	...
½	0.109 (2.77)	0.85 (1.27)	std	40	2500 (17.2)	...
	0.147 (3.73)	1.09 (1.62)	XS	80	2500 (17.2)	...
	0.294 (7.47)	1.71 (2.55)	XXS	...	2500 (17.2)	...
¾	0.113 (2.87)	1.13 (1.68)	std	40	2500 (17.2)	...
	0.154 (3.91)	1.47 (2.19)	XS	80	2500 (17.2)	...
	0.308 (7.82)	2.44 (3.63)	XXS	...	2500 (17.2)	...

TABLE X1.2 *Continued*

NPS Designator	Wall Thickness in. (mm)	Nominal Weight lb/ft (kg/m)	Weight Class psi (MPa)	Schedule No. psi (MPa)	Test Pressure Grade I	Test Pressure Grade II
1	0.133 (3.38)	1.68 (2.50)	std	40	2500 (17.2)	...
	0.179 (4.55)	2.17 (3.23)	XS	80	2500 (17.2)	...
	0.358 (9.09)	3.66 (5.45)	XXS	...	2500 (17.2)	...
1¼	0.140 (3.56)	2.27 (3.38)	std	40	2500 (17.2)	...
	0.191 (4.85)	3.00 (4.47)	XS	80	2500 (17.2)	...
	0.382 (9.70)	5.21 (7.76)	XXS	...	...	2500 (17.2)
1½	0.145 (3.68)	2.72 (4.05)	std	40	2500 (17.2)	...
	0.200 (5.08)	3.63 (5.41)	XS	80	2500 (17.2)	...
	0.400 (10.16)	6.41 (9.55)	XXS	...	...	2500 (17.2)
2	0.154 (3.91)	3.65 (5.44)	std	40	2500 (17.2)	...
	0.218 (5.54)	5.02 (7.48)	XS	80	2500 (17.2)	...
	0.344 (8.74)	7.46 (11.12)	...	160	2500 (17.2)	...
	0.436 (11.07)	9.03 (13.45)	XXS	...	...	2500 (17.2)
2½	0.203 (5.16)	5.79 (8.62)	std	40	2500 (17.2)	...
	0.276 (7.01)	7.66 (11.41)	XS	80	2500 (17.2)	...
	0.375 (9.52)	10.01 (14.91)	...	160	2500 (17.2)	...
	0.552 (14.02)	13.70 (20.41)	XXS	...	...	2500 (17.2)
3	0.216 (5.49)	7.58 (11.29)	std	40	2500 (17.2)	...
	0.300 (7.62)	10.25 (15.27)	XS	80	2500 (17.2)	...
	0.438 (11.13)	14.32 (21.34)	...	160	...	2500 (17.2)
	0.600 (15.24)	18.58 (27.67)	XXS	...	...	2500 (17.2)
3½	0.226 (5.74)	9.11 (13.57)	std	40	2400 (16.5)	...
	0.318 (8.08)	12.51 (18.63)	XS	80	2800 (19.3)	...
4	0.237 (6.02)	10.79 (16.07)	std	40	2200 (15.2)	...
	0.337 (8.56)	14.98 (22.31)	XS	80	2800 (19.3)	...
	0.438 (11.13)	19.00 (28.30)	...	120	...	2800 (19.3)
	0.531 (13.49)	22.51 (33.53)	...	160	...	2800 (19.3)
	0.674 (17.12)	27.54 (41.02)	XXS	...	...	2800 (19.3)
5	0.258 (6.55)	14.62 (21.78)	std	40	1900 (13.1)	...
	0.375 (9.52)	20.78 (30.95)	XS	80	2800 (19.3)	...
	0.500 (12.70)	27.04 (40.28)	...	120	...	2800 (19.3)
	0.625 (15.88)	32.96 (49.09)	...	160	...	2800 (19.3)
	0.750 (19.05)	38.55 (57.42)	XXS	...	...	2800 (19.3)
6	0.280 (7.11)	18.97 (28.26)	std	40	1800 (12.4)	...
	0.432 (10.97)	28.57 (42.56)	XS	80	...	2300 (15.9)
	0.562 (14.27)	36.39 (54.20)	...	120	...	2800 (19.3)
	0.719 (18.26)	45.35 (67.55)	...	160	...	2800 (19.3)
	0.864 (21.95)	53.16 (79.68)	XXS	...	...	2800 (19.3)
8	0.250 (6.35)	22.36 (33.31)	...	20	1200 (8.3)	...
	0.277 (7.04)	24.70 (36.79)	...	30	1300 (9.0)	...
	0.322 (8.18)	28.55 (42.53)	std	40	1600 (11.0)	...
	0.406 (10.31)	35.64 (53.10)	...	60	...	1700 (11.7)
	0.500 (12.70)	43.39 (64.63)	XS	80	...	2100 (14.5)
	0.594 (15.09)	50.95 (75.92)	...	100	...	2500 (17.2)
	0.719 (18.26)	60.71 (90.43)	...	120	...	2800 (19.3)
	0.812 (20.62)	67.76 (100.96)	...	140	...	2800 (19.3)
	0.875 (22.22)	72.42 (107.87)	XXS	...	...	2800 (19.3)
	0.906 (23.01)	74.69 (111.29)	...	160	...	2800 (19.3)
10	0.250 (6.35)	28.04 (41.77)	...	20	1000 (6.9)	...
	0.279 (7.09)	31.20 (46.47)	...	...	1100 (7.6)	...
	0.307 (7.80)	34.24 (51.00)	...	30	1200 (8.3)	...
	0.365 (9.27)	40.48 (60.29)	std	40	1400 (9.7)	...
	0.500 (12.70)	54.74 (81.55)	XS	60	...	1700 (11.7)
	0.594 (15.09)	64.43 (96.00)	...	80	...	2000 (13.8)
	0.719 (18.26)	77.03 (114.74)	...	100	...	2400 (16.5)
	0.844 (21.44)	89.29 (133.04)	...	120	...	2800 (9.3)
	1.000 (25.40)	104.13 (155.15)	XXS	140	...	2800 (9.3)
	1.125 (28.58)	115.65 (172.32)	...	160	...	2800 (9.3)
12	0.250 (6.35)	33.38 (49.72)	...	20	800 (5.5)	...
	0.330 (8.38)	43.77 (65.20)	...	30	1100 (7.6)	...
	0.375 (9.52)	49.56 (73.82)	std	...	1200 (8.3)	...
	0.406 (10.31)	53.52 (79.74)	...	40	...	1100 (7.6)
	0.500 (12.70)	65.42 (97.44)	XS	...	...	1400 (9.7)
	0.562 (14.27)	73.15 (108.96)	...	60	...	1600 (11.0)
	0.688 (17.48)	88.63 (132.01)	...	80	...	1900 (13.1)
	0.844 (21.44)	107.32 (159.91)	...	100	...	2400 (16.5)
	1.000 (25.40)	125.49 (186.98)	XXS	120	...	2800 (19.3)
	1.125 (28.58)	139.68 (208.12)	...	140	...	2800 (19.3)
	1.312 (33.32)	160.27 (238.80)	...	160	...	2800 (19.3)
14	0.250 (6.35)	36.71 (54.68)	...	10	750 (5.2)	...

TABLE X1.2 *Continued*

NPS Designator	Wall Thickness	Nominal Weight	Weight Class	Schedule No.	Test Pressure	
					Grade I	Grade II
	in. (mm)	lb/ft (kg/m)	psi (MPa)	psi (MPa)		
	0.312 (7.92)	45.61 (67.94)	...	20	950 (6.6)	...
	0.375 (9.52)	54.57 (81.28)	std	30	1100 (7.6)	...
	0.438 (11.13)	63.44 (94.49)	...	40	...	1100 (7.6)
	0.500 (12.70)	72.09 (107.38)	XS	...	...	1300 (9.0)
	0.594 (15.09)	85.05 (126.72)	...	60	...	1500 (10.3)
	0.750 (19.05)	106.13 (158.08)	...	80	...	1900 (13.1)
	0.938 (23.83)	130.85 (194.90)	...	100	...	2400 (16.5)
	1.094 (27.79)	150.79 (234.68)	...	120	...	2800 (19.3)
	1.250 (31.75)	170.22 (253.63)	...	140	...	2800 (19.3)
	1.406 (35.71)	189.11 (281.77)	...	160	...	2800 (19.3)
16	0.250 (6.35)	42.05 (62.63)	...	10	650 (4.5)	...
	0.312 (7.92)	52.27 (77.86)	...	20	800 (5.5)	...
	0.375 (9.52)	62.58 (93.21)	std	30	1000 (6.9)	...
	0.500 (12.70)	82.77 (123.29)	XS	40	...	1100 (7.6)
	0.656 (16.66)	107.50 (160.18)	...	60	...	1500 (10.3)
	0.844 (21.44)	136.62 (203.56)	...	80	...	1900 (13.1)
	1.031 (26.19)	164.82 (245.58)	...	100	...	2300 (15.9)
	1.219 (30.96)	192.43 (286.72)	...	120	...	2700 (18.6)
	1.438 (36.52)	223.64 (333.22)	...	140	...	2800 (19.3)
	1.594 (40.49)	245.25 (365.42)	...	160	...	2800 (19.3)
18	0.250 (6.35)	47.39 (70.59)	...	10	600 (4.1)	...
	0.312 (7.92)	58.94 (87.79)	...	20	750 (5.2)	...
	0.375 (9.52)	70.59 (105.14)	std	...	900 (6.2)	...
	0.438 (11.13)	82.15 (122.36)	...	30	...	900 (6.2)
	0.500 (12.70)	93.45 (139.19)	XS	...	...	1000 (6.9)
	0.562 (14.27)	104.67 (155.91)	...	40	...	1100 (7.6)
	0.750 (19.05)	138.17 (205.80)	...	60	...	1500 (10.3)
	0.938 (23.83)	170.92 (254.59)	...	80	...	1900 (13.1)
	1.156 (29.36)	207.96 (309.86)	...	100	...	2300 (15.9)
	1.375 (34.92)	244.14 (363.77)	...	120	...	2800 (19.3)
	1.562 (39.67)	274.22 (408.54)	...	140	...	2800 (19.3)
	1.781 (45.24)	308.50 (459.67)	...	160	...	2800 (19.3)
20	0.250 (6.35)	52.73 (78.54)	...	10	500 (3.4)	...
	0.375 (9.52)	78.60 (117.07)	std	20	800 (5.5)	...
	0.500 (12.70)	104.13 (155.10)	XS	30	...	900 (6.2)
	0.594 (15.09)	123.11 (183.43)	...	40	...	1100 (7.6)
	0.812 (20.62)	166.40 (247.85)	...	60	...	1500 (10.3)
	1.031 (26.19)	208.87 (311.22)	...	80	...	1900 (13.1)
	1.281 (32.54)	256.10 (381.59)	...	100	...	2300 (15.9)
	1.500 (38.10)	296.37 (441.59)	...	120	...	2700 (18.6)
	1.750 (44.45)	341.10 (508.24)	...	140	...	2800 (19.3)
	1.969 (50.01)	379.17 (564.96)	...	160	...	2800 (19.3)
24	0.250 (6.35)	63.41 (94.45)	...	10	450 (3.1)	...
	0.375 (9.52)	94.62 (140.94)	std	20	650 (4.5)	...
	0.500 (12.70)	125.49 (186.92)	XS	...	...	750 (5.2)
	0.562 (14.27)	140.68 (209.54)	...	30	...	850 (5.9)
	0.688 (17.48)	171.29 (255.14)	...	40	...	1000 (6.9)
	0.969 (24.61)	238.85 (355.89)	...	60	...	1500 (10.3)
	1.219 (30.96)	296.58 (441.90)	...	80	...	1800 (12.4)
	1.531 (38.89)	367.39 (547.41)	...	100	...	2300 (15.9)
	1.812 (46.02)	429.39 (639.79)	...	120	...	2700 (18.6)
	2.062 (52.37)	483.12 (719.85)	...	140	...	2800 (19.3)
	2.344 (59.64)	542.14 (807.79)	...	160	...	2800 (19.3)
26	0.250 (6.35)	68.75 (102.40)	...	...	400 (2.8)	...
	0.312 (7.92)	85.60 (127.50)	...	10	500 (3.4)	...
	0.375 (9.52)	102.63 (152.87)	std	...	610 (4.2)	...
	0.500 (12.70)	136.17 (202.83)	XS	20	...	690 (4.8)

Designation: A 523 – 96 (Reapproved 2005)

Standard Specification for Plain End Seamless and Electric-Resistance-Welded Steel Pipe for High-Pressure Pipe-Type Cable Circuits[1]

This standard is issued under the fixed designation A 523; 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 covers seamless and electric-resistance-welded steel pipe used as conduit for the installation of high-pressure pipe-type electrical cables in NPS 4 to NPS 12, inclusive, with nominal (average) wall thicknesses 0.219 to 0.562 in., depending on size. Pipe having other dimensions (Note 2) may be furnished, provided such pipe complies with all other requirements of this specification.

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."

NOTE 2—A comprehensive listing of standardized pipe dimensions is contained in ANSI B36.10.

1.2 Pipe ordered under this specification is suitable for welding and for forming operations involving flaring, belling, and bending.

1.3 Pipe for this purpose shall be furnished in Grade A or Grade B as specified in the purchase order. Grade A is more suitable for forming operations involving bending, flaring, or belling and this grade is normally preferred. This provision is not intended to prohibit the cold bending, flaring, or belling of Grade B pipe.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 The following hazard caveat applies to the test method portion, Section 20, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition [3]

2.2 *ANSI Standard:*

B36.10 Welded and Seamless Wrought Steel Pipe[4]

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 or number of lengths),

3.1.2 Name of material (steel pipe),

3.1.3 Method of manufacture (seamless or electric-resistance-welded),

3.1.4 Grade (Table 1),

3.1.5 Size (outside diameter and nominal wall thickness or weight per foot),

3.1.6 Length when other than specified in Section 13,

3.1.7 End finish (Section 16),

3.1.8 Skelp for tension tests, if permitted 20.2,

3.1.9 When mill applied coating is required (Section 10), and

3.1.10 ASTM specification number.

4. Process

4.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

4.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The

[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 A01.09 on Carbon Steel Tubular Products.

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This specification was initiated by the IEEE Insulated Conductors Committee in recognition of the need for a specification embodying the special requirements of pipe for high-voltage electrical circuits. It was prepared for acceptance as an ASTM specification by a task group of Subcommittee A01.09 of ASTM Committee A01.

[2] 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.

[3] Withdrawn.

[4] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

TABLE 1 Tensile Requirements

	Grade A	Grade B
Tensile strength, min, ksi (MPa)	48 (330)	60 (415)
Yield strength, min, ksi (MPa)	30 (205)	35 (240)
Elongation in 2 in. or 50 mm, %:		
Basic minimum elongation for walls 5⁄16 in. (7.94 mm) and over in thickness, longitudinal strip tests, and for small sizes tested in full section.	35	30
When standard round 2-in. or 50-mm gage length test specimen is used	28	22
For longitudinal strip tests, the width of the gage section shall be 1½ in. (38.1 mm) and a deduction for each 1⁄32 in. (0.79 mm) decrease in wall thickness below 5⁄16 in. (7.94 mm) from the basic minimum elongation of the following percentage points	1.75[A]	1.50[A]

[A] The following table[B] gives the minimum computed values:

Wall Thickness		Elongation in 2 in. or 50 mm, min, %	
in.	mm	Grade A	Grade B
5⁄16 (0.312)	7.94	35.0	30.0
9⁄32 (0.281)	7.14	33.2	28.5
1⁄4 (0.250)	6.35	31.5	27.0
7⁄32 (0.219)	5.56	29.8	25.5
3⁄16 (0.188)	4.76	28.0	24.0
5⁄32 (0.156)	3.97	26.2	22.5
1⁄8 (0.125)	3.18	24.5	21.0
3⁄32 (0.094)	2.38	22.8	19.5
1⁄16 (0.062)	1.59	21.0	18.0

[B] This table gives the computed minimum elongation values for each 1⁄32 in. (0.79 mm) decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

Grade	Equation
A	$E = 56t + 17.50$
B	$E = 48t + 15.00$

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

producer shall remove the transition material by any established procedure that positively separates the grades.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2 and the chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

TABLE 2 Chemical Requirements

	Composition, %							
	Carbon, max		Manganese, max		Phosphorus, max		Sulfur, max	
	Heat	Product	Heat	Product	Heat	Product	Heat	Product
Grade A								
Seamless	0.22	0.25	0.90	0.95	0.035	0.045	0.050	0.060
E.R.W.[A]	0.21	0.25	0.90	0.95	0.035	0.045	0.050	0.060
Grade B								
Seamless	0.27	0.30	1.15	1.20	0.035	0.045	0.050	0.060
E.R.W.[A]	0.26	0.30	1.15	1.20	0.035	0.045	0.050	0.060

[A] Electric-Resistance-Welded pipe.

6. Heat Analysis

6.1 When specified in the purchase order, the manufacturer shall report the heat analysis of each heat of steel used in the manufacture of pipe to this specification. The analysis shall conform to the requirements specified in Section 5 for the grade of pipe ordered.

7. Product Analysis

7.1 When specified in the purchase order, a product analysis report shall be furnished by the manufacturer on two pipes from each lot of 400 lengths, or fraction thereof, of 4½-in. outside diameter and 5 9⁄16-in. outside diameter sizes and from each lot of 200 lengths, or fraction thereof, of each size 6⅝-in. outside diameter through 12¾-in. outside diameter pipe. Samples for chemical analysis, except for spectrographic analysis, shall be taken in accordance with Practice E 59. The chemical composition thus determined shall conform to the requirements specified in Section 5.

7.2 *Product Analysis Retests*—If both lengths of pipe representing the lot fail the specified product analysis, the lot shall be rejected, or at the option of the manufacturer, all of the remaining lengths of the lot shall be tested individually for conformance to the specified requirements. If only one of the lengths of pipe representing the lot fails the specified check analysis, the lot shall be rejected or, at the option of the manufacturer, two retest analyses shall be made on two additional lengths selected from the same lot. If both of these retest analyses conform to the specified requirements, the lot shall be accepted except for the length which failed on the initial analysis. If one or both of the retest analyses fail the specified requirements, the entire lot shall be rejected, or, at the option of the manufacturer, each of the remaining lengths shall be tested individually. Only analysis of the rejecting element or elements is necessary in checking the remaining lengths.

8. Tensile Requirements

8.1 The material shall conform to the requirements as to tensile properties prescribed in Table 1.

8.2 The yield point shall be determined by the drop of the beam or by the halt in the gauge of the testing machine, by the use of dividers, or by other approved methods. When a definite yield point is not exhibited, the yield strength corresponding to a permanent offset of 0.2 % of the gauge length of the specimen or to a total extension of 0.5 % of the gauge length of the specimen under load shall be determined.

8.3 The test specimen taken across the weld shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe ordered. This test will not be required for pipe under NPS 8.

9. Flattening Test Requirements

9.1 *Seamless Pipe*—For seamless pipe, a section not less than 2½ in. (63.5 mm) in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, no cracks or breaks on the inside or outside or end surfaces, except as provided for in 9.5, shall occur until the distance between the plates is less than the value of *H* calculated by the following equation:

$$H = \frac{(1+e)t}{e+\frac{t}{D}} \quad (1)$$

where:
H = distance between flattening plates, in. (mm),
e = deformation per unit length (constant for a given grade of steel, 0.09 for Grade A and 0.07 for Grade B),
t = specified wall thickness, in. (mm), and
D = specified outside diameter, in. (mm).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material that is revealed during the entire flattening test shall be cause for rejection.

9.2 *Electric-Resistance-Welded Pipe*—A specimen at least 4 in. (101.6 mm) in length shall be flattened cold between parallel plates in three steps with the weld located either 0 or 90° from the line of direction of force as required in 9.2.1 during the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces shall occur until the distance between the plates is less than two thirds of the original outside diameter of the pipe. As a second step, the flattening shall be continued. During the second step, which is test for ductility exclusive of the weld, no cracks or breaks on the inside or outside surfaces, except as provided for in 9.5, shall occur until the distance between the plates is less than one third of the original outside diameter of the pipe but is not less than five times the wall thickness of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

9.2.1 For pipe produced in single lengths, the flattening test specified in 9.2 shall be made on both crop ends cut from each length of pipe. The tests from each end shall be made alternately with the weld at 0° and at 90° from the line of direction of force. For pipe produced in multiple lengths, the flattening test shall be made on crop ends representing the front and back of each coil with the weld at 90° from the line of direction of force, and on two intermediate rings representing each coil with the weld 0° from the line of direction of force.

9.3 Surface imperfections in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements in Section 15.

9.4 Superficial ruptures as a result of surface imperfections shall not be cause for rejection.

9.5 When low D-to-t ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than ten.

10. Coatings

10.1 Unless otherwise specified, the pipe shall not be given a mill coating of paint, oil, or any other material either inside or outside.

11. Dimensions and Weight

11.1 Dimensions and weight of pipe included in this specification are listed in Table 3.

12. Dimensions, Weight, and Permissible Variations

12.1 *Weight*—The weight of the pipe as specified in Table 3 shall not vary by more than the following amounts:

Extra-strong and lighter wall thickness	±5 %
Minimum permissible length	±10 %

12.2 *Diameter*—The outside diameter shall not vary more than ±1 % from the diameter specified. Pipe NPS 10 and smaller shall not be more than 1⁄64 in. (0.4 mm) smaller and NPS 12 pipe shall not be more than 1⁄32-in. (0.8-mm) smaller than the tabulated outside diameter for a distance of 4 in. (101.6 mm) from the end. The pipe shall permit passage over the ends for a distance of 4 in. of a ring gauge having a bore 1⁄16-in. larger than the tabulated diameter of NPS 10 and smaller pipe, and a bore 3⁄32 in. (2.4 mm) larger for NPS 12 pipe.

TABLE 3 Dimensions, Weight, and Test Pressures

NPS Desig- nator	Outside Di- ameter, in.	Wall Thickness		Nominal Weight		Test Pressure			
						Grade A		Grade B	
		in.	mm	lb/ft	kg/m	psi	MPa	psi	MPa
4	4½	0.237	6.02	10.79	16.1	1900	13.10	2200	15.17
		0.250	6.35	11.35	16.9	2000	13.79	2300	15.86
		0.281	7.14	12.66	18.8	2200	15.17	2500	17.24
		0.312	7.92	13.96	20.7	2500	17.24	2500	17.24
5	5 9⁄16	0.219	5.56	12.50	18.6	1400	9.65	1700	11.72
		0.258	6.55	14.62	21.8	1700	11.72	1900	13.10
		0.281	7.14	15.85	23.6	1800	12.41	2100	14.48
		0.312	7.92	17.50	26.0	2000	13.79	2400	16.55
		0.344	8.74	19.17	28.6	2200	15.17	2500	17.24
6	6⅝	0.250	6.35	17.02	25.3	1400	9.65	1600	11.03
		0.280	7.11	18.97	28.2	1500	10.34	1800	12.41
		0.312	7.92	21.04	31.3	1700	11.72	2000	13.79
		0.344	8.74	23.08	34.3	1900	13.10	2200	15.17
		0.375	9.52	25.03	37.2	2000	13.79	2400	16.55
		0.500[A]	12.70[A]	32.71[A]	48.7[A]	2500	17.24	2500	17.24
8	8⅝	0.250	6.35	22.36	33.3	1000	6.89	1200	8.27
		0.277	7.04	24.70	36.8	1200	8.27	1300	8.96
		0.312	7.92	27.70	41.2	1300	8.96	1500	10.34
		0.322	8.18	28.55	42.6	1300	8.96	1600	11.03
		0.344	8.74	30.42	45.3	1400	9.65	1700	11.72
		0.375	9.52	33.04	49.2	1600	11.03	1800	12.41
		0.438	11.13	38.30	57.0	1800	12.41	2100	14.48
		0.500	12.70	43.39	64.6	2100	14.48	2400	16.55
10	10¾	0.250	6.35	28.04	41.7	850	5.86	1000	6.89
		0.279	7.09	31.20	46.4	1000	6.89	1200	8.27
		0.307	7.80	34.24	50.9	1000	6.89	1200	8.27
		0.344	8.74	38.23	56.9	1100	7.58	1300	8.96
		0.365	9.27	40.48	60.2	1200	8.27	1400	9.65
		0.438	11.13	48.24	71.6	1500	10.34	1700	11.72
		0.500	12.70	54.74	8.15	1700	11.72	2000	13.79
		0.562[A]	14.27[A]	61.15[A]	91.0[A]	1900	13.10	2200	15.17
12	12¾	0.250	6.35	33.38	49.7	700	4.83	800	5.52
		0.281	7.14	37.42	55.7	800	5.52	950	6.55
		0.312	7.92	41.45	61.7	900	6.21	1000	6.89
		0.330	8.38	43.77	65.1	1000	6.89	1200	8.27
		0.344	8.74	45.58	67.8	1000	6.89	1200	8.27
		0.375	9.52	49.56	73.7	1100	7.58	1200	8.27
		0.438	11.13	57.59	86.7	1200	8.27	1400	9.65
		0.500	12.70	65.42	97.3	1400	9.65	1600	11.03
		0.562[A]	14.27[A]	73.15[A]	108.8[A]	1600	11.03	1900	13.10

[A] Designates weights heavier than extra-strong.

12.3 *Thickness*—The minimum wall thickness at any point shall not be more than 12.5 % under, or the maximum thickness more than 15.0 % over, the nominal wall thickness specified.

13. Lengths

13.1 Unless otherwise specified in the purchase order, the finished length of pipe for the entire shipment shall conform to the following:

Minimum permissible length	35 ft 0 in. (10.7 m)
Maximum permissible length	50 ft 0 in. (15.2 m)

14. Jointers

14.1 Jointers shall not be permitted.

15. Workmanship

15.1 The condition of the inside of the pipe is of utmost importance to avoid damage to the cable during installation.

15.2 The pipe bore shall be smooth and free of protruding weld beads, slivers, or any other projections that cannot be readily removed with a power wire brush or by shot, sand, or grit blasting. The internal finish of the longitudinal seam of electric-resistance-welded pipe shall be smooth and free of sharp edges and sharp grooves. The interior of all pipes shall be free of loose scale. Pipe ends shall not be rounded out by hammering.

15.3 The finished pipe shall be reasonably straight and free of laminations and defects. Any imperfection shall be considered a defect when the depth is in excess of 12½ % of the tabulated wall thickness of the pipe.

16. End Finish

16.1 When pipe ends are to be flared for butt-welding with the use of backing rings, the ends shall be beveled to an angle of 30 +5, −0° measured from a line drawn perpendicular to the axis of the pipe, and with a root face of $\frac{1}{16} \pm \frac{1}{32}$ in. (1.6 ± 0.8 mm). The pipe ends shall have burrs removed from both the inside and outside edges.

16.2 When pipe ends are to be prepared for bell and spigot jointing, the ends shall be cut square with the axis of the pipe. The inside and outside edges shall be smooth and free of burrs.

17. Repair of Defects

17.1 Repair of defects in seamless pipe and in the base metal of welded pipe shall be permissible except where:

17.1.1 More than one repair is required in any length equivalent to ten times the tabulated outside diameter of the pipe,

17.1.2 Where the depth exceeds 33⅓ % of the tabulated wall thickness, and

17.1.3 Where the length of the defect, in which the depth exceeds 12½ % of the wall thickness, is greater than 25 % of the tabulated outside diameter of the pipe.

17.2 All repairs shall be made by removing the defect completely, thoroughly cleaning the cavity, and then welding. Each length of repaired pipe shall be tested hydrostatically in accordance with Section 19.

17.3 No repair of the longitudinal weld is permitted.

18. Number of Tests and Retests

18.1 One of each of the tests specified in Sections 8 and 9, except 9.2, shall be made on one length of pipe from each lot of 500 lengths, or fraction thereof, of each size. A length is defined as the length as ordered, except that in the case of orders for cut lengths shorter than single random, the term lot shall apply to the lengths as rolled, prior to cutting to the required short lengths.

18.2 The number of flattening tests required for electric-resistance-welded pipe shall be as given in 9.2.1.

18.3 Each length of pipe shall be subjected to the hydrostatic test specified in Section 19.

18.4 If the results of the mechanical tests of any lot do not conform to the requirements specified in Sections 8 and 9, except 9.2.1, retests may be made on additional pipe of double the original number tested from the same lot, each test conforming to the requirements specified.

18.5 If any section of the pipe fails to comply with the requirements of 9.2 for pipe produced in single lengths, other sections may be cut from the same end of the same length until satisfactory tests are obtained, except that the finished pipe shall not be shorter than 80 % of its length after the initial cropping; otherwise, the length shall be rejected. For pipe produced in multiple lengths, retests may be cut from each end of each individual length in the multiple. Such tests shall be made with the weld alternately 0° and 90° from the line of direction of force.

19. Hydrostatic Test

19.1 Each length of pipe shall be tested at the mill to the hydrostatic pressures prescribed in Table 3. The hydrostatic pressure shall be maintained for not less than 5 s.

20. Test Methods

20.1 The test specimens and the tests required by this specification shall conform to those described in the latest issue of Test Methods and Definitions A 370. When impracticable to pull a test specimen in full thickness, the standard 2-in. or 50-mm gauge length tension test specimen shown in Fig. 6 of Test Methods and Definitions A 370 may be used.

20.2 The longitudinal tension test specimen shall be taken from the end of the pipe or, by agreement between the manufacturer and the purchaser, may be taken from the skelp, at a point approximately 90° from the weld, and shall not be flattened between gauge marks. The sides of each specimen shall be parallel between gauge marks.

20.3 Transverse weld test specimens from electric-welded pipe shall be taken with the weld at the center of the specimen. All transverse test specimens shall be approximately 1½ in. (38.1 mm) wide in the gauge length and shall represent the full wall thickness of the pipe from which the specimen was cut.

20.4 Test specimens for flattening tests shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free of burrs, except when made on crop ends taken from welded pipe.

20.5 All specimens shall be tested at room temperature.

21. Inspection

21.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

22. Rejection

22.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in this specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

22.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

23. Product Marking

23.1 Each length of pipe shall be legibly marked by rolling, stamping, or stenciling to show the name or brand of the manufacturer; the kind of pipe, that is, seamless (S) or electric resistance welded (E); grade; outside diameter; weight per foot or wall thickness; and the specification number (see Appendix X1).

23.2 *Bar Coding*—In addition to the requirements in 23.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

APPENDIX

(Nonmandatory Information)

X1. DEFINITIONS OF TYPES OF PIPE

X1.1 *Type E, Electric-Resistance-Welded Pipe*—Pipe produced in individual lengths or in continuous lengths from coiled skelp and subsequently cut into individual lengths, having a longitudinal butt joint wherein coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which the pipe is a part, and by the application of pressure.

X1.2 *Type S, Wrought Steel Seamless Pipe*—A tubular product made without a welded seam. It is manufactured by hot working steel and if necessary, by subsequently cold finishing the hot-worked tubular product to produce the desired shape, dimensions, and properties.

Designation: A 522/A 522M – 07

Standard Specification for Forged or Rolled 8 and 9% Nickel Alloy Steel Flanges, Fittings, Valves, and Parts for Low-Temperature Service[1]

This standard is issued under the fixed designation A 522/A 522M; 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 8 and 9 % nickel-alloy steel forged or rolled flanges, fittings, valves, and parts intended for use in welded pressure vessels for low-temperature service. The specification is applicable to forgings with maximum section thickness of 3 in. [75 mm] in the double normalized and tempered condition and 5 in. [125 mm] in the quenched and tempered condition. Forgings under this specification are intended for service at operating temperatures not lower than −320 °F [−196 °C] for Type I or −275 °F [−170 °C] for Type II or higher than 250 °F [121 °C].

1.2 Material under this specification is available in two types having different chemical compositions as follows:

Type	Nominal Nickel Content, %
I	9
II	8

1.3 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

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.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 788/A 788M Specification for Steel Forgings, General Requirements

A 961/A 961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

3. General Requirements and Ordering Information

3.1 Product furnished to this specification shall conform to the requirements of Specification A 961, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 961 constitutes nonconformance with this specification.

3.2 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to furnish the needed material. Examples of such information include but are not limited to the ordering information in Specification A 961 and following:

3.2.1 Any supplementary requirements, and

3.2.2 Additional requirements, (See 4.5, 5.2, 6.1, 7.2, and 10.3).

4. Materials and Manufacture

4.1 The steel shall be produced in accordance with the melting process section of Specification A 788.

4.2 Material for forgings shall consist of ingots, or either forged or rolled blooms, billets, or bars.

4.3 The finished product shall be a forging as defined in the Terminology Section of Specification A 788.

4.4 Except for flanges of all types, hollow cylindrically shaped parts may be made from hot-rolled or forged bar, provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Except for all types of flanges, elbows, return bends, tees, and header tees, other parts up to and including NPS 4 may be machined from hot-rolled or forged bar.

4.5 When specified in the order, the manufacturer shall submit for purchaser's approval a sketch showing the shape of the rough forging before machining.

5. Chemical Composition

5.1 The steel shall conform to the requirements of Table 1.

5.2 If required by the purchaser, product analysis may be performed in accordance with the requirements of A 961.

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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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-522 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.

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

TABLE 1 Chemical Requirements

	Composition, %	
	Type I	Type II
Carbon, max	0.13	0.13
Manganese, max	0.90	0.90
Phosphorus, max	0.025	0.025
Sulfur, max	0.025	0.025
Silicon[A]	0.15–0.30	0.15–0.30
Nickel	8.5–9.5	7.5–8.5

[A] When vacuum carbon deoxidation is used, the maximum silicon content shall be 0.10 %.

6. Heat Treatment

6.1 The forgings shall be heat treated by the manufacturer by either of the following methods as mutually agreed upon between the purchaser and the manufacturer.

6.1.1 *Quenched and Tempered*—Heat to a uniform temperature of 1475 ± 25 °F [800 ± 15 °C]; hold at this temperature for a minimum time of 1 h/in. [2.5 min/mm] of thickness but in no case less than 30 min; quench by immersion in circulating water. Reheat until the forging attains 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. [2.5 min/mm] of thickness but in no case less than 30 min; cool in air or water quench, at a rate not less than 300 °F [165 °C]/h.

6.1.2 *Double Normalized and Tempered*— Heat to a uniform temperature of 1650 °F [900 °C]; hold at this temperature for a minimum time of 1 h/in. [2.5 min/mm] of thickness but in no case less than 30 min; cool in air. Reheat until the forging attains a uniform temperature of 1450 °F [790 °C]; hold at this temperature for a minimum time of 1 h/in. [2.5 min/mm] of thickness but in no case less than 30 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. [2.5 min/mm] of thickness but in no case less than 30 min; cool in air or water quench, at a rate not less than 300 °F [165 °C]/h.

6.2 When stress relieving is to be performed after fabrication, the recommended stress-relieving treatment is as follows: gradually and uniformly heat the steel to a temperature between 1025 and 1085 °F [550 and 585 °C]; hold for a minimum of 2 h for thicknesses up to 1 in. [25 mm]. For thicknesses over 1 in. [25 mm], a minimum additional holding time in the ratio of 1 h/in. [2.5 min/mm] of thickness in excess of 1 in. [25 mm] shall be added. Cool at a minimum rate of 300 °F [165 °C]/h to a temperature not exceeding 600 °F [315 °C].

7. Mechanical Properties

7.1 *Tension Test*—Forgings to Types 1 and 2 shall conform to the tensile requirements of Table 2.

7.2 *Impact Test*—The Charpy impact test requirements in Table 3 shall be met unless Supplementary Requirement S2 of this specification has been specified.

TABLE 2 Tensile Requirements at Room Temperature

Tensile strength, min, ksi [MPa]	100 [690]
Yield strength, min, (0.2 % off-set), ksi [MPa]	75 [515]
Elongation in 2 in. [50mm], min, %	22
Reduction of area, min, %	45

TABLE 3 Charpy V-Notch Lateral Expansion Requirements For Standard Size [10 X 10 mm] Specimens

Type	Lateral expansion in. [mm]	Temperature °F [°C][A]	Report absorbed energy and % shear fracture
1	0.015 [0.38]	–320 [–195]	Yes
2	0.015 [0.38]	–275 [–170]	Yes

[A] Except when Supplementary Requirement S2 is specified.

7.2.1 The values for energy absorption and the fracture appearance in percentage of shear fracture for each specimen shall be recorded and reported for information.

8. Workmanship, Finish, and Appearance

8.1 The forgings shall have a workman-like finish and shall be free of injurious defects.

9. Number of Tests and Retests

9.1 At least one tension test and one set of Charpy V-notch impact tests shall be made from each heat in each heat-treatment charge.

9.2 If the results of the mechanical tests do not conform to the specified requirements, the manufacturer may retreat the forgings, but not more than three additional times. Retreatment involves re-austenitizing the forgings. Retests shall be made in accordance with this section.

9.3 If the lateral expansion result from one Charpy impact specimen falls below 0.015in. [0.38mm], but not less than 0.010in. [0.25mm], and the average test result equals or exceeds 0.015mm [0.38mm], then one retest of three additional specimens may be made. The lateral expansion obtained from each of the three retest specimens shall equal or exceed 0.015in. [0.38mm].

10. Test Specimens

10.1 The test specimens shall be located at any point midway between the center and surface of solid forgings, and at any point mid-thickness of the heaviest section of hollow or bored forgings. For solid forgings where test metal is provided on the periphery, test specimens shall be taken at mid-thickness of the test prolongation.

10.2 Tests shall be oriented so that the longitudinal axis of the specimen is parallel to the major direction of grain flow.

10.3 When fabrication requires stress relieving, the purchaser shall specify stress relieving of the test pieces prior to machining of the test specimens. Stress relieving shall be carried out as prescribed in 6.2.

11. Method of Impact Testing

11.1 The impact test shall be made in accordance with the simple beam, Charpy type of test described in the latest issue of Test Methods and Definitions A 370.

11.2 Precaution shall be taken so that when broken, the test specimens shall be within ± 3 °F [1.7 °C] of the specified test temperature.

12. Inspection

12.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

12.2 The manufacturer shall report to the purchaser or the purchaser's representative the heat treatments applied to the material and to the test blocks and the results of the chemical analysis and mechanical tests made in accordance with this specification and the heat number or his heat identification.

13. Rejection

13.1 Unless otherwise specified, any rejection based on tests made in accordance with Section 5 and 7 shall be reported to the manufacturer within 60 days from the receipt of samples or test reports by the purchaser.

13.2 Each forging in which injurious metal defects are exposed during subsequent machining shall be rejected and the manufacturer notified.

14. Certification

14.1 Test reports, when required, shall include certification that all requirements of this specification have been met. The manufacturer shall provide the following where applicable:

14.1.1 Whether Type 1 or Type 11 material has been supplied and the chemical analysis results in accordance with Section 5,

14.1.2 Type of heat treatment used,

14.1.3 Results of tension and Charpy impact tests (together with absorbed energy and % shear fracture) including the impact test temperature, and test coupon stress relief details if applicable,

14.1.4 Results of any additional or supplementary requirements specified by the purchaser, and

14.1.5 The year date and revision letter, if any, of the specification. Note, this information is not required to be marked on the forgings.

15. Product Marking

15.1 Each forging shall be legibly stamped by the manufacturer with the heat number or his heat identification, the manufacturer's name (see Note 1) or trademark, and this specification number, A 522 or A 522M as applicable, 8NI, or 9NI, and QT or NNT as applicable.

NOTE 1—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

15.2 Forgings impact tested at a temperature other than that specified in Table 3, by the use of Supplementary Requirement S2, shall be marked with the letters LTV following the specification number, as well as the temperature scale used. For forgings to A 522, these letters shall be followed by the impact test temperature in degrees Fahrenheit. A prefix 0 to the test temperature indicates a temperature below 0 °F, for example A 522 Type 1 LTV0300F indicates −300 °F. For forgings to A 522M, the letters LTV shall be followed by the impact test temperature in degrees Celsius. A prefix 0 to the test temperature indicates a temperature below 0 °C, for example A 522M Type 1 LTV0150C indicates –150 °C.

15.3 The purchaser may specify additional identification marking and the location of all stamping. The type of stamps shall be round or "interrupted-dot" die stamps having a radius of 1⁄32 in. [0.8 mm].

15.4 *Bar Coding*—In addition to the requirements in 15.1, 15.2, and 15.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

16. Keywords

16.1 low temperature applications; nickel alloy steel; pipe fittings; steel; piping applications; pressure containing parts; steel flanges; steel forgings; alloy; steel valves

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements described below may be included in purchaser's order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirement details not fully described shall be agreed upon between the purchaser and the supplier, but shall not negate any of the requirements in the body of the specification.

S1. Nondestructive Tests

S1.1 *Ultrasonic Tests*—Ultrasonic tests may be made by agreement between manufacturer and purchaser.

S1.2 *Liquid Penetrant Tests*—Liquid penetrant tests may be made by agreement between manufacturer and purchaser.

S2. Other Impact Test Temperatures

S2.1 The purchaser may specify an impact test temperature higher than that in Table 3 but no higher than the minimum intended operating temperature for the forging.

S2.2 Marking shall be in accordance with 15.2.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 522/A 522M – 06, that may impact the use of this specification. (Approved March 1, 2007)

(*1*) Revised marking requirements in 15.2.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 522/A 522M – 01, that may impact the use of this specification. (Approved December 1, 2006)

(*1*) Revised SI cooling rate in Section 6.

(*2*) Revised 15.1 and 15.2 to reference SI temperatres.

Standard Specification for Seamless Carbon and Alloy Steel Mechanical Tubing[1]

This standard is issued under the fixed designation A 519; 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. This standard replaces QQ-T-00825 and QQ-T-830.

1. Scope*

1.1 This specification covers several grades of carbon and alloy steel seamless mechanical tubing. The grades are listed in Tables 1-3. When welding is used for joining the weldable mechanical tube grades, the welding procedure shall be suitable for the grade, the condition of the components, and the intended service.

1.2 This specification covers both seamless hot-finished mechanical tubing and seamless cold-finished mechanical tubing in sizes up to and including 12 ¾ in. (323.8 mm) outside diameter for round tubes with wall thicknesses as required.

1.3 The tubes shall be furnished in the following shapes, as specified by the purchaser: round, square, rectangular, and special sections.

1.4 Supplementary requirements of an optional nature are provided and when desired shall be so stated in the order.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 1040 Guide for Specifying Harmonized Standard Grade Compositions for Wrought Carbon, Low-Alloy, and Alloy Steels

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[3]

2.2 *Military Standards:*

TABLE 1 Chemical Requirements of Low-Carbon Steels

Grade Designation	Chemical Composition Limits, %			
	Carbon[A]	Manganese[B]	Phosphorus,[B] max	Sulfur,[B] max
MT 1010	0.05–0.15	0.30–0.60	0.040	0.050
MT 1015	0.10–0.20	0.30–0.60	0.040	0.050
MT X 1015	0.10–0.20	0.60–0.90	0.040	0.050
MT 1020	0.15–0.25	0.30–0.60	0.040	0.050
MT X 1020	0.15–0.25	0.70–1.00	0.040	0.050

[A] Limits apply to heat and product analyses.
[B] Limits apply to heat analysis; except as required by 6.1, product analyses are subject to the applicable additional tolerances given in Table 5.

TABLE 2 Chemical Requirements of Other Carbon Steels

Grade Designation	Chemical Composition Limits, %[A]			
	Carbon	Manganese	Phosphorus, max	Sulfur, max
1008	0.10 max	0.30–0.50	0.040	0.050
1010	0.08–0.13	0.30–0.60	0.040	0.050
1012	0.10–0.15	0.30–0.60	0.040	0.050
1015	0.13–0.18	0.30–0.60	0.040	0.050
1016	0.13–0.18	0.60–0.90	0.040	0.050
1017	0.15–0.20	0.30–0.60	0.040	0.050
1018	0.15–0.20	0.60–0.90	0.040	0.050
1019	0.15–0.20	0.70–1.00	0.040	0.050
1020	0.18–0.23	0.30–0.60	0.040	0.050
1021	0.18–0.23	0.60–0.90	0.040	0.050
1022	0.18–0.23	0.70–1.00	0.040	0.050
1025	0.22–0.28	0.30–0.60	0.040	0.050
1026	0.22–0.28	0.60–0.90	0.040	0.050
1030	0.28–0.34	0.60–0.90	0.040	0.050
1035	0.32–0.38	0.60–0.90	0.040	0.050
1040	0.37–0.44	0.60–0.90	0.040	0.050
1045	0.43–0.50	0.60–0.90	0.040	0.050
1050	0.48–0.55	0.60–0.90	0.040	0.050
1518	0.15–0.21	1.10–1.40	0.040	0.050
1524	0.19–0.25	1.35–1.65	0.040	0.050
1541	0.36–0.44	1.35–1.65	0.040	0.050

[A] The ranges and limits given in this table apply to heat analysis; except as required by 6.1, product analyses are subject to the applicable additional tolerances given in Table Number 5.

[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 A01.09 on Carbon Steel Tubular Products.

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[2] 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.

[3] Withdrawn.

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

MIL-STD-129 Marking for Shipment and Storage[4]
MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[4]

2.3 *Federal Standard:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[4]

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, weight, or number of pieces),

3.1.2 Name of material (seamless carbon or alloy steel mechanical tubing),

3.1.3 Form (round, square, rectangular or special shapes, Section 1),

3.1.4 Dimensions (round, outside diameters and wall thickness, Section 8; square and rectangular, outside dimensions and wall thickness, Section 9; other, specify),

3.1.5 Length (specific or random, mill lengths, see 8.5 and 9.5),

3.1.6 Manufacture (hot finished or cold finished, 4.5 and 4.6),

3.1.7 Grade (Section 5),

3.1.8 Condition (sizing method and thermal treatment, Section 12),

3.1.9 Surface finish (special pickling, shot blasting, or ground outside surface, if required),

3.1.10 Specification designation,

3.1.11 Individual supplementary requirements, if required,

3.1.12 End use, if known,

3.1.13 Packaging,

3.1.14 Product analysis and chemical analysis, if required (Section 6 and Section 7),

3.1.15 Specific requirements, or exceptions to this specification,

3.1.16 Special marking (Section 15), and

3.1.17 Special packing (Section 16).

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 3 Chemical Requirements for Alloy Steels

NOTE 1—The ranges and limits in this table apply to steel not exceeding 200 in.^{2} (1290 cm^2) in cross-sectional area.

NOTE 2—Small quantities of certain elements are present in alloy steels which are not specified or required. These elements are considered as incidental and may be present to the following maximum amounts: copper, 0.35 %; nickel, 0.25 %; chromium, 0.20 %; molybdenum, 0.10 %.

NOTE 3—The ranges and limits given in this table apply to heat analysis; except as required by 6.1, product analyses are subject to the applicable additional tolerances given in Table Number 5.

Grade[A,B] Designation	Chemical Composition Limits, %							
	Carbon	Manganese	Phosphorus,[C] max	Sulfur,[C,D] max	Silicon	Nickel	Chromium	Molybdenum
1330	0.28–0.33	1.60–1.90	0.040	0.040	0.15–0.35	...	...	...
1335	0.33–0.38	1.60–1.90	0.040	0.040	0.15–0.35	...	...	...
1340	0.38–0.43	1.60–1.90	0.040	0.040	0.15–0.35	...	...	...
1345	0.43–0.48	1.60–1.90	0.040	0.040	0.15–0.35	...	...	...
3140	0.38–0.43	0.70–0.90	0.040	0.040	0.15–0.35	1.10–1.40	0.55–0.75	...
E3310	0.08–0.13	0.45–0.60	0.025	0.025	0.15–0.35	3.25–3.75	1.40–1.75	...
4012	0.09–0.14	0.75–1.00	0.040	0.040	0.15–0.35	...	...	0.15–0.25
4023	0.20–0.25	0.70–0.90	0.040	0.040	0.15–0.35	...	...	0.20–0.30
4024	0.20–0.25	0.70–0.90	0.040	0.035−0.050	0.15–0.35	...	...	0.20–0.30
4027	0.25–0.30	0.70–0.90	0.040	0.040	0.15–0.35	...	...	0.20–0.30
4028	0.25–0.30	0.70–0.90	0.040	0.035−0.050	0.15–0.35	...	...	0.20–0.30
4037	0.35–0.40	0.70–0.90	0.040	0.040	0.15–0.35	...	...	0.20–0.30
4042	0.40–0.45	0.70–0.90	0.040	0.040	0.15–0.35	...	...	0.20–0.30
4047	0.45–0.50	0.70–0.90	0.040	0.040	0.15–0.35	...	...	0.20–0.30
4063	0.60–0.67	0.75–1.00	0.040	0.040	0.15–0.35	...	...	0.20–0.30
4118	0.18–0.23	0.70–0.90	0.040	0.040	0.15–0.35	...	0.40–0.60	0.08–0.15
4130	0.28–0.33	0.40–0.60	0.040	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
4135	0.32–0.39	0.65–0.95	0.040	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
4137	0.35–0.40	0.70–0.90	0.040	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
4140	0.38–0.43	0.75–1.00	0.040	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
4142	0.40–0.45	0.75–1.00	0.040	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
4145	0.43–0.48	0.75–1.00	0.040	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
4147	0.45–0.50	0.75–1.00	0.040	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
4150	0.48–0.53	0.75–1.00	0.040	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
4320	0.17–0.22	0.45–0.65	0.040	0.040	0.15–0.35	1.65–2.00	0.40–0.60	0.20–0.30
4337	0.35–0.40	0.60–0.80	0.040	0.040	0.15–0.35	1.65–2.00	0.70–0.90	0.20–0.30
E4337	0.35–0.40	0.65–0.85	0.025	0.025	0.15–0.35	1.65–2.00	0.70–0.90	0.20–0.30
4340	0.38–0.43	0.60–0.80	0.040	0.040	0.15–0.35	1.65–2.00	0.70–0.90	0.20–0.30
E4340	0.38–0.43	0.65–0.85	0.025	0.025	0.15–0.35	1.65–2.00	0.70–0.90	0.20–0.30
4422	0.20–0.25	0.70–0.90	0.040	0.040	0.15–0.35	...	...	0.35–0.45
4427	0.24–0.29	0.70–0.90	0.040	0.040	0.15–0.35	...	...	0.35–0.45
4520	0.18–0.23	0.45–0.65	0.040	0.040	0.15–0.35	...	...	0.45–0.60

TABLE 3 *Continued*

Grade[A,B] Designation	Chemical Composition Limits, %							
	Carbon	Manganese	Phosphorus,[C] max	Sulfur,[C,D] max	Silicon	Nickel	Chromium	Molybdenum
4615	0.13–0.18	0.45–0.65	0.040	0.040	0.15–0.35	1.65–2.00	...	0.20–0.30
4617	0.15–0.20	0.45–0.65	0.040	0.040	0.15–0.35	1.65–2.00	...	0.20–0.30
4620	0.17–0.22	0.45–0.65	0.040	0.040	0.15–0.35	1.65–2.00	...	0.20–0.30
4621	0.18–0.23	0.70–0.90	0.040	0.040	0.15–0.35	1.65–2.00	...	0.20–0.30
4718	0.16–0.21	0.70–0.90	0.040	0.040	0.15–0.35	0.90–1.20	0.35–0.55	0.30–0.40
4720	0.17–0.22	0.50–0.70	0.040	0.040	0.15–0.35	0.90–1.20	0.35–0.55	0.15–0.25
4815	0.13–0.18	0.40–0.60	0.040	0.040	0.15–0.35	3.25–3.75	...	0.20–0.30
4817	0.15–0.20	0.40–0.60	0.040	0.040	0.15–0.35	3.25–3.75	...	0.20–0.30
4820	0.18–0.23	0.50–0.70	0.040	0.040	0.15–0.35	3.25–3.75	...	0.20–0.30
5015	0.12–0.17	0.30–0.50	0.040	0.040	0.15–0.35	...	0.30–0.50	...
5046	0.43–0.50	0.75–1.00	0.040	0.040	0.15–0.35	...	0.20–0.35	...
5115	0.13–0.18	0.70–0.90	0.040	0.040	0.15–0.35	...	0.70–0.90	...
5120	0.17–0.22	0.70–0.90	0.040	0.040	0.15–0.35	...	0.70–0.90	...
5130	0.28–0.33	0.70–0.90	0.040	0.040	0.15–0.35	...	0.80–1.10	...
5132	0.30–0.35	0.60–0.80	0.040	0.040	0.15–0.35	...	0.75–1.00	...
5135	0.33–0.38	0.60–0.80	0.040	0.040	0.15–0.35	...	0.80–1.05	...
5140	0.38–0.43	0.70–0.90	0.040	0.040	0.15–0.35	...	0.70–0.90	...
5145	0.43–0.48	0.70–0.90	0.040	0.040	0.15–0.35	...	0.70–0.90	...
5147	0.46–0.51	0.70–0.95	0.040	0.040	0.15–0.35	...	0.85–1.15	...
5150	0.48–0.53	0.70–0.90	0.040	0.040	0.15–0.35	...	0.70–0.90	...
5155	0.51–0.59	0.70–0.90	0.040	0.040	0.15–0.35	...	0.70–0.90	...
5160	0.56–0.64	0.75–1.00	0.040	0.040	0.15–0.35	...	0.70–0.90	...
52100[E]	0.93–1.05	0.25–0.45	0.025	0.015	0.15–0.35	0.25 max	1.35–1.60	0.10 max
E50100	0.98–1.10	0.25–0.45	0.025	0.025	0.15–0.35	...	0.40–0.60	...
E51100	0.98–1.10	0.25–0.45	0.025	0.025	0.15–0.35	...	0.90–1.15	...
E52100	0.98–1.10	0.25–0.45	0.025	0.025	0.15–0.35	...	1.30–1.60	...
								Vanadium
6118	0.16–0.21	0.50–0.70	0.040	0.040	0.15–0.35	...	0.50–0.70	0.10–0.15
6120	0.17–0.22	0.70–0.90	0.040	0.040	0.15–0.35	...	0.70–0.90	0.10 min
6150	0.48–0.53	0.70–0.90	0.040	0.040	0.15–0.35	...	0.80–1.10	0.15 min
						Aluminum		Molybdenum
E7140	0.38–0.43	0.50–0.70	0.025	0.025	0.15–0.40	0.95–1.30	1.40–1.80	0.30–0.40
						Nickel		
8115	0.13–0.18	0.70–0.90	0.040	0.040	0.15–0.35	0.20–0.40	0.30–0.50	0.08–0.15
8615	0.13–0.18	0.70–0.90	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8617	0.15–0.20	0.70–0.90	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8620	0.18–0.23	0.70–0.90	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8622	0.20–0.25	0.70–0.90	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8625	0.23–0.28	0.70–0.90	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8627	0.25–0.30	0.70–0.90	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8630	0.28–0.33	0.70–0.90	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8637	0.35–0.40	0.75–1.00	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8640	0.38–0.43	0.75–1.00	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8642	0.40–0.45	0.75–1.00	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8645	0.43–0.48	0.75–1.00	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8650	0.48–0.53	0.75–1.00	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8655	0.51–0.59	0.75–1.00	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8660	0.55–0.65	0.75–1.00	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8720	0.18–0.23	0.70–0.90	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.20–0.30
8735	0.33–0.38	0.75–1.00	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.20–0.30
8740	0.38–0.43	0.75–1.00	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.20–0.30
8742	0.40–0.45	0.75–1.00	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.20–0.30
8822	0.20–0.25	0.75–1.00	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.30–0.40
9255	0.51–0.59	0.60–0.80	0.040	0.040	1.80–2.20	...	0.60–0.80	...
9260	0.56–0.64	0.75–1.00	0.040	0.040	1.80–2.20	...	...	...
9262	0.55–0.65	0.75–1.00	0.040	0.040	1.80–2.20	...	0.25–0.40	...
E9310	0.08–0.13	0.45–0.65	0.025	0.025	0.15–0.35	3.00–3.50	1.00–1.40	0.08–0.15

TABLE 3 *Continued*

Grade[A,B] Designation	Chemical Composition Limits, %							
	Carbon	Manganese	Phosphorus,[C] max	Sulfur,[C,D] max	Silicon	Nickel	Chromium	Molybdenum
9840	0.38–0.42	0.70–0.90	0.040	0.040	0.15–0.35	0.85–1.15	0.70–0.90	0.20–0.30
9850	0.48–0.53	0.70–0.90	0.040	0.040	0.15–0.35	0.85–1.15	0.70–0.90	0.20–0.30
50B40	0.38–0.42	0.75–1.00	0.040	0.040	0.15–0.35	...	0.40–0.60	...
50B44	0.43–0.48	0.75–1.00	0.040	0.040	0.15–0.35	...	0.40–0.60	...
50B46	0.43–0.50	0.75–1.00	0.040	0.040	0.15–0.35	...	0.20–0.35	...
50B50	0.48–0.53	0.74–1.00	0.040	0.040	0.15–0.35	...	0.40–0.60	...
50B60	0.55–0.65	0.75–1.00	0.040	0.040	0.15–0.35	...	0.40–0.60	...
51B60	0.56–0.64	0.75–1.00	0.040	0.040	0.15–0.35	...	0.70–0.90	...
81B45	0.43–0.48	0.75–1.00	0.040	0.040	0.15–0.35	0.20–0.40	0.35–0.55	0.08–0.15
86B45	0.43–0.48	0.75–1.00	0.040	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
94B15	0.13–0.18	0.75–1.00	0.040	0.040	0.15–0.35	0.30–0.60	0.30–0.50	0.08–0.15
94B17	0.15–0.20	0.75–1.00	0.040	0.040	0.15–0.35	0.30–0.60	0.30–0.50	0.08–0.15
94B30	0.28–0.33	0.75–1.00	0.040	0.040	0.15–0.35	0.30–0.60	0.30–0.50	0.08–0.15
94B40	0.38–0.43	0.75–1.00	0.040	0.040	0.15–0.35	0.30–0.60	0.30–0.50	0.08–0.15

[A] Grades shown in this table with prefix letter E generally are manufactured by the basic-electric-furnace process. All others are normally manufactured by the basic-open-hearth process but may be manufactured by the basic-electric-furnace process with adjustments in phosphorus and sulfur.
[B] Grades shown in this table with the letter B, such as 50B40, can be expected to have 0.0005 % minimum boron control.
[C] The phosphorus sulfur limitations for each process are as follows:

Basic electric furnace	0.025 max %	Acid electric furnace	0.050 max %
Basic open hearth	0.040 max %	Acid open hearth	0.050 max %

[D] Minimum and maximum sulfur content indicates resulfurized steels.
[E] The purchaser may specify the following maximum amounts: copper, 0.30 %; aluminum, 0.050 %; and oxygen, 0.0015 %.

4. Materials and Manufacture

4.1 The steel may be made by any process.

4.2 If a specific type of melting is required by the purchaser, it shall be as stated on the purchase order.

4.3 The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting, such as electroslag or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

4.5 Tubes shall be made by a seamless process and shall be either hot finished or cold finished, as specified.

4.6 Seamless tubing is a tubular product made without a welded seam. It is manufactured usually by hot working steel and, if necessary, by subsequently cold finishing the hot-worked tubular product to produce the desired shape, dimensions and properties.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1 (Low Carbon MT Grades), Table 2 (Higher Carbon Steels), Table 3 (Alloy Standard Steels (see Guide A 1040)) and Table 4 (Resulfurized or Rephosphorized, or Both, Carbon Steels (see Guide A 1040)).

5.2 Grade MT1015 or MTX1020 will be supplied at the producer's option, when no grade is specified.

TABLE 4 Chemical Requirements of Resulfurized or Rephosphorized, or Both, Carbon Steels[A]

Grade Designation	Chemical Composition Limits, %				
	Carbon	Manganese	Phosphorus	Sulfur	Lead
1118	0.14–0.20	1.30–1.60	0.040 max	0.08–0.13	
11L18	0.14–0.20	1.30–1.60	0.040 max	0.08–0.13	0.15–0.35
1132	0.27–0.32	1.35–1.65	0.040 max	0.08–0.13	
1137	0.32–0.39	1.35–1.65	0.040 max	0.08–0.13	
1141	0.37–0.45	1.35–1.65	0.040 max	0.08–0.13	
1144	0.40–0.48	1.35–1.65	0.040 max	0.24–0.33	
1213	0.13 max	0.70–1.00	0.07–0.12	0.24–0.33	
12L14	0.15 max	0.85–1.15	0.04–0.09	0.26–0.35	0.15–0.35
1215	0.09 max	0.75–1.05	0.04–0.09	0.26–0.35	

[A] The ranges and limits given in this table apply to heat analysis; except as required by 6.1, product analyses are subject to the applicable additional tolerances given in Table Number 5.

5.3 When a carbon steel grade is 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 and Table 2 is not permitted.

5.4 Analyses of steels other than those listed are available. To determine their availability, the purchaser should contact the producer.

6. Heat Analysis

6.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified; if secondary melting processes are used, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The heat analysis shall conform to the requirements specified, except that where the heat identity has not been maintained or where the analysis is not sufficiently complete to permit conformance to be determined, the chemical composition determined from a product analysis made by the tubular manufacturer shall conform to the requirements specified for heat analysis. When requested in the order or contract, a report of such analyses shall be furnished to the purchaser.

7. Product Analysis

7.1 Except as required by 6.1, a product analysis by the manufacturer shall be required only when requested in the order.

7.1.1 *Heat Identity Maintained*—One product analysis per heat on either billet or tube.

7.1.2 *Heat Identity Not Maintained*—A product analysis from one tube per 2000 ft (610 m) or less for sizes over 3 in. (76.2 mm), and one tube per 5000 ft (1520 m) or less for sizes 3 in. (76.2 mm) and under.

7.2 Samples for chemical analysis, except for spectrochemical analysis, shall be taken in accordance with Practice E 59. The composition thus determined shall correspond to the requirements in the applicable section or Tables 1-5 of this specification and shall be reported to the purchaser or the purchaser's representative.

7.3 If the original test for check analysis fails, retests of two additional billets 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 producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

TABLE 6 Outside Diameter Tolerances for Round Hot-Finished Tubing[A,B,C]

Outside Diameter Size Range, in. (mm)	Outside Diameter Tolerance, in. (mm) Over	Under
Up to 2.999 (76.17)	0.020 (0.51)	0.020 (0.51)
3.000–4.499 (76.20–114.27)	0.025 (0.64)	0.025 (0.64)
4.500–5.999 (114.30–152.37)	0.031 (0.79)	0.031 (0.79)
6.000–7.499 (152.40–190.47)	0.037 (0.94)	0.037 (0.94)
7.500–8.999 (190.50–228.57)	0.045 (1.14)	0.045 (1.14)
9.000–10.750 (228.60–273.05)	0.050 (1.27)	0.050 (1.27)

[A] Diameter tolerances are not applicable to normalized and tempered or quenched and tempered conditions.
[B] The common range of sizes of hot finished tubes is 1½ in. (38.1 mm) to 10¾ in. (273.0 mm) outside diameter with wall thickness at least 3 % or more of outside diameter, but not less than 0.095 in. (2.41 mm).
[C] Larger sizes are available; consult manufacturer for sizes and tolerances.

8. Permissible Variations in Dimensions of Round Tubing

8.1 *Hot-Finished Mechanical Tubing*—Hot-finished mechanical tubing is produced to outside diameter and wall thickness. Variations in outside diameter and wall thickness shall not exceed the tolerances shown in Table 6 and Table 7. Table 6 and Table 7 cover these tolerances and apply to the specified size.

8.2 *Cold-Worked Mechanical Tubing*:

8.2.1 Variations in outside diameter, inside diameter and wall thickness shall not exceed the tolerances shown in Table 8 and Table 9.

TABLE 5 Product Analysis Tolerances Over or Under Specified Range or Limit

NOTE 1—Individual determinations may vary from the specified heat limits or ranges to the extent shown in this table except that any element in a heat may not vary both above and below a specified range.

NOTE 2—In all types of steel, because of the degree to which phosphorus and sulfur segregate, product analysis for these elements is not technologically appropriate for rephosphorized or resulfurized steels unless misapplication is clearly indicated.

Carbon Steel Seamless Tubes

Element	Limit, or Maximum of Specified Range, %	Tolerance, Over the Maximum Limit or Under the Minimum Limit, % Under min	Over max
Carbon	to 0.25, incl	0.02	0.02
	over 0.25 to 0.55, incl	0.03	0.03
	over 0.55	0.04	0.04
Manganese	to 0.90, incl	0.03	0.03
	over 0.90 to 1.65, incl	0.06	0.06
Phosphorus	basic steel to 0.05, incl	. . .	0.008
	acid-bessemer steel to 0.12, incl	. . .	0.010
Sulfur	to 0.06, incl	. . .	0.008
Silicon	to 0.35, incl	0.02	0.02
	over 0.35 to 0.60, incl	0.05	0.05
Copper	. . .	0.02	0.02

Alloy Steel Seamless Tube

Elements	Limit, or Maximum of Specified Element, %	Tolerance Over Maximum Limit or Under Minimum Limit for Size Ranges Shown, % 100 in.^{2} (645 cm^2) or less	Over 100 to 200 in.^{2} (645 to 1290 cm^2), incl
Carbon	to 0.30, incl	0.01	0.02
	over 0.30 to 0.75, incl	0.02	0.03
	over 0.75	0.03	0.04
Manganese	to 0.90, incl	0.03	0.04
	over 0.90 to 2.10, incl	0.04	0.05
Phosphorus	over max, only	0.005	0.010
Sulfur	to 0.060, incl	0.005	0.010
Silicon	to 0.35, incl	0.02	0.02
	over 0.35 to 2.20, incl	0.05	0.06
Nickel	to 1.00, incl	0.03	0.03
	over 1.00 to 2.00, incl	0.05	0.05
	over 2.00 to 5.30, incl	0.07	0.07
	over 5.30 to 10.00, incl	0.10	0.10
Chromium	to 0.90, incl	0.03	0.04
	over 0.90 to 2.10, incl	0.05	0.06
	over 2.10 to 3.99, incl	0.10	0.10
Molybdenum	to 0.20, incl	0.01	0.01
	over 0.20 to 0.40, incl	0.02	0.03
	over 0.40 to 1.15, incl	0.03	0.04
Vanadium	to 0.10, incl	0.01	0.01
	over 0.10 to 0.25, incl	0.02	0.02
	over 0.25 to 0.50, incl	0.03	0.03
	min value specified, check under min limit	0.01	0.01
Tungsten	to 1.00, incl	0.04	0.05
	over 1.00 to 4.00, incl	0.08	0.09
Aluminum	up to 0.10, incl	0.03	. . .
	over 0.10 to 0.20, incl	0.04	. . .
	over 0.20 to 0.30, incl	0.05	. . .
	over 0.30 to 0.80, incl	0.07	. . .
	over 0.80 to 1.80, incl	0.10	. . .

8.2.2 Cold-worked mechanical tubing is normally produced to outside diameter and wall thickness. If the inside diameter is

TABLE 7 Wall Thickness Tolerances for Round Hot-Finished Tubing

Wall Thickness Range as Percent of Outside Diameter	Wall Thickness Tolerance,[A] percent Over and Under Nominal		
	Outside Diameter 2.999 in. (76.19 mm) and smaller	Outside Diameter 3.000 in. (76.20 mm) to 5.999 in. (152.37 mm)	Outside Diameter 6.000 in. (152.40 mm) to 10.750 in. (273.05 mm)
Under 15	12.5	10.0	10.0
15 and over	10.0	7.5	10.0

[A] Wall thickness tolerances may not be applicable to walls 0.199 in. (5.05 mm) and less; consult manufacturer for wall tolerances on such tube sizes.

a more important dimension, then cold-worked tubing should be specified to inside diameter and wall thickness or outside diameter and inside diameter.

8.3 *Rough-Turned Mechanical Tubing*—Variation in outside diameter and wall thickness shall not exceed the tolerance in Table 10. Table 10 covers tolerances as applied to outside diameter and wall thickness and applies to the specified size.

8.4 *Ground Mechanical Tubing*—Variation in outside diameter shall not exceed the tolerances in Table 11. This product is normally produced from a cold-worked tube.

8.5 *Lengths*—Mechanical tubing is commonly furnished in mill lengths, 5 ft (1.5 m) and over. Definite cut lengths are furnished when specified by the purchaser. Length tolerances are shown in Table 12.

8.6 *Straightness*—The straightness tolerances for seamless round tubing shall not exceed the amounts shown in Table 13.

9. Permissible Variations in Dimensions of Square and Rectangular Tubing

9.1 Variations in outside dimensions and wall thickness shall not exceed the tolerances shown in Table 14 unless otherwise specified by the manufacturer and the purchaser. The wall thickness dimensions shall not apply at the corners.

9.2 *Corner Radii*—The corners of a square and a rectangular tube will be slightly rounded inside and rounded outside consistent with the wall thickness. The outside corner may be slightly flattened. The radii of corners for square and rectangular cold finished tubing shall be in accordance with Table 15.

9.3 *Squareness Tolerance*:

9.3.1 Permissible variations for squareness for the side of square and rectangular tubing shall be determined by the following equation:

$$\pm b = c \times 0.006$$

where:
b = tolerance for out-of-square, in. (mm), and
c = largest external dimension across flats, in. (mm).

9.3.2 The squareness of sides is commonly determined by one of the following methods:

9.3.2.1 A square, with two adjustable contact points on each arm, is placed on two sides. A fixed feeler gage is then used to measure the maximum distance between the free contact point and the surface of the tubing.

9.3.2.2 A square, equipped with direct-reading vernier, may be used to determine the angular deviation which in turn may be related to distance, in inches.

9.4 *Twist Tolerance*:

9.4.1 Twist tolerance for square and rectangular tubing shall be in accordance with Table 16. The twist tolerance in square and rectangular tubing may be measured by holding one end of the square or rectangular tube on a surface plate with the bottom side parallel to the surface plate and noting the height at either corner of the opposite end of the same side above the surface plate.

9.4.2 Twist may also be measured by the use of a beveled protractor, equipped with a level, and noting the angular deviation on opposite ends or at any point throughout the length.

9.5 *Lengths*—Square and rectangular tubing is commonly furnished in mill lengths 5 ft (1.5 m) and over. Definite cut lengths are furnished when specified by the purchaser. Length tolerances are shown in Table 17.

9.6 *Straightness*—Straightness for square and rectangular tubing shall be 0.060 in. in any 3 ft (1.67 mm in 1 m).

10. Machining Allowances

10.1 For the method of calculating the tube size required to cleanup in machining to a particular finished part, see Appendix X1.

11. Workmanship, Finish, and Appearance

11.1 The tubing shall be free of laps, cracks, seams, and other defects as is consistent with good commercial practice. The surface finish will be compatible with the condition to which it is ordered.

12. Condition

12.1 The purchaser shall specify a sizing method and, if required, a thermal treatment.

12.1.1 *Sizing Methods*:

12.1.1.1 HF—Hot Finished,

12.1.1.2 CW—Cold Worked,

12.1.1.3 RT—Rough Turned,

12.1.1.4 G—Ground.

12.1.2 *Thermal Treatments*:

12.1.2.1 A—Annealed,

12.1.2.2 N—Normalized,

12.1.2.3 QT—Quenched and Tempered,

12.1.2.4 SR—Stress Relieved or Finish Anneal.

13. Coating

13.1 When specified, tubing shall be coated with a film of oil before shaping to retard rust. Should the order specify that tubing be shipped without rust retarding oil, the film of oils incidental to manufacture will remain on the surface. If the order specifies no oil, the purchaser assumes responsibility for rust in transit.

13.2 Unless otherwise specified, tubing may be coated with a rust retarding oil on the outside and inside surfaces, at the option of the manufacturer.

TABLE 8 Outside and Inside Diameter Tolerances for Round Cold-Worked Tubing[A,B,C]

Outside Diameter Size Range, in.[D]	Wall Thickness As Percent of Outside Diameter	Thermal Treatment after Final Cold Work Producing Size											
		None, or not exceeding 1100 °F Nominal Temperature				Heated Above 1100 °F Nominal Temperature Without Accelerated Cooling				Quenched and Tempered			
		OD, in.[D]		ID, in.[D]		OD, in.[D]		ID, in.[D]		OD, in.[D]		ID, in.[D]	
		Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Up to 0.499	all	0.004	0.000	—	—	0.005	0.002	—	—	0.010	0.010	0.010	0.010
0.500–1.699	all	0.005	0.000	0.000	0.005	0.007	0.002	0.002	0.007	0.015	0.015	0.015	0.015
1.700–2.099	all	0.006	0.000	0.000	0.006	0.006	0.005	0.005	0.006	0.020	0.020	0.020	0.020
2.100–2.499	all	0.007	0.000	0.000	0.007	0.008	0.005	0.005	0.008	0.023	0.023	0.023	0.023
2.500–2.899	all	0.008	0.000	0.000	0.008	0.009	0.005	0.005	0.009	0.025	0.025	0.025	0.025
2.900–3.299	all	0.009	0.000	0.000	0.009	0.011	0.005	0.005	0.011	0.028	0.028	0.028	0.028
3.300–3.699	all	0.010	0.000	0.000	0.010	0.013	0.005	0.005	0.013	0.030	0.030	0.030	0.030
3.700–4.099	all	0.011	0.000	0.000	0.011	0.013	0.007	0.010	0.010	0.033	0.033	0.033	0.033
4.100–4.499	all	0.012	0.000	0.000	0.012	0.014	0.007	0.011	0.011	0.036	0.036	0.036	0.036
4.500–4.899	all	0.013	0.000	0.000	0.013	0.016	0.007	0.012	0.012	0.038	0.038	0.038	0.038
4.900–5.299	all	0.014	0.000	0.000	0.014	0.018	0.007	0.013	0.013	0.041	0.041	0.041	0.041
5.300–5.549	all	0.015	0.000	0.000	0.015	0.020	0.007	0.014	0.014	0.044	0.044	0.044	0.044
5.550–5.559	under 6	0.010	0.010	0.010	0.010	0.018	0.018	0.018	0.018				
	6 to 7½	0.009	0.009	0.009	0.009	0.016	0.016	0.016	0.016				
	over 7½	0.018	0.000	0.009	0.009	0.017	0.015	0.016	0.016				
6.000–6.499	under 6	0.013	0.013	0.013	0.013	0.023	0.023	0.023	0.023				
	6 to 7½	0.010	0.010	0.010	0.010	0.018	0.018	0.018	0.018				
	over 7½	0.020	0.000	0.010	0.010	0.020	0.015	0.018	0.018				
6.500–6.999	under 6	0.015	0.015	0.015	0.015	0.027	0.027	0.027	0.027				
	6 to 7½	0.012	0.012	0.012	0.012	0.021	0.021	0.021	0.021				
	over 7½	0.023	0.000	0.012	0.012	0.026	0.015	0.021	0.021				
7.000–7.499	under 6	0.018	0.018	0.018	0.018	0.032	0.032	0.032	0.032				
	6 to 7½	0.013	0.013	0.013	0.013	0.023	0.023	0.023	0.023				
	over 7½	0.026	0.000	0.013	0.013	0.031	0.015	0.023	0.023				
7.500–7.999	under 6	0.020	0.020	0.020	0.020	0.035	0.035	0.035	0.035				
	6 to 7½	0.015	0.015	0.015	0.015	0.026	0.026	0.026	0.026				
	over 7½	0.029	0.000	0.015	0.015	0.036	0.015	0.026	0.026				
8.000–8.499	under 6	0.023	0.023	0.023	0.023	0.041	0.041	0.041	0.041				
	6 to 7½	0.016	0.016	0.016	0.016	0.028	0.028	0.028	0.028				
	over 7½	0.031	0.000	0.015	0.016	0.033	0.022	0.028	0.028				
8.500–8.999	under 6	0.025	0.025	0.025	0.025	0.044	0.044	0.044	0.044				
	6 to 7½	0.017	0.017	0.017	0.017	0.030	0.030	0.030	0.030				
	over 7½	0.034	0.000	0.015	0.019	0.038	0.022	0.030	0.030				
9.000–9.499	under 6	0.028	0.028	0.028	0.028	0.045	0.045	0.049	0.049				
	6 to 7½	0.019	0.019	0.019	0.019	0.033	0.033	0.033	0.033				
	over 7½	0.037	0.000	0.015	0.022	0.043	0.022	0.033	0.033				
9.500–9.999	under 6	0.030	0.030	0.030	0.030	0.045	0.045	0.053	0.053				
	6 to 7½	0.020	0.020	0.020	0.020	0.035	0.035	0.035	0.035				
	over 7½	0.040	0.000	0.015	0.025	0.048	0.022	0.035	0.035				
10.000–10.999	under 6	0.034	0.034	0.034	0.034	0.045	0.045	0.060	0.060				
	6 to 7½	0.022	0.022	0.022	0.022	0.039	0.039	0.039	0.039				
	over 7½	0.044	0.000	0.015	0.029	0.055	0.022	0.039	0.039				
11.000–12.000	under 6	0.035	0.035	0.035	0.035	0.050	0.050	0.065	0.065				
	6 to 7½	0.025	0.025	0.025	0.025	0.045	0.045	0.045	0.045				
	over 7½	0.045	0.000	0.015	0.035	0.060	0.022	0.045	0.045				

[A] Many tubes with inside diameter less than 50 % of outside diameter or with wall thickness more than 25 % of outside diameter, or with wall thickness over 1¼ in., or weighing more than 90 lb/ft, are difficult to draw over a mandrel. Therefore, the inside diameter can vary over or under by an amount equal to 10 % of the wall thickness. See also Footnote *B*.

[B] For those tubes with inside diameter less than ½ in. (or less than ⅝ in. when the wall thickness is more than 20 % of the outside diameter), which are not commonly drawn over a mandrel, Footnote *A* is not applicable. Therefore, for those tubes, the inside diameter is governed by the outside diameter tolerance shown in this table and the wall thickness tolerances shown in Table Number 9.

[C] Tubing having a wall thickness less than 3 % of the outside diameter cannot be straightened properly without a certain amount of distortion. Consequently such tubes, while having an average outside diameter and inside diameter within the tolerances shown in this table, require an ovality tolerance of ½ % over and under nominal outside diameter, this being in addition to the tolerances indicated in this table.

[D] 1 in. = 25.4 mm.

TABLE 9 Wall Thickness Tolerances for Round Cold-Worked Tubing

Wall Thickness Range as % of Outside Diameter	Wall Thickness Tolerance Over and Under Nominal, %	
	Up to 1.499 in., ID	1.500 in. and Over
25 and Under	10.0	7.5
Over 25	12.5	10.0

14. Rejection

14.1 Tubes that fail to meet the requirements of this specification shall be set aside and the manufacturer shall be notified.

15. Product and Package Marking

15.1 *Civilian Procurement*—Each box, bundle or lift, and, when individual pieces are shipped, each piece shall be

TABLE 10 Outside Diameter and Wall Tolerances for Rough-Turned Seamless Steel Tubing

Specified Size Outside Diameter, in. (mm)	Outside Diameter, in. (mm)		Wall Thickness, %	
	Plus	Minus	Plus	Minus
Up to but not including 6¾ (171.4)	0.005 (0.13)	0.005 (0.13)	12.5	12.5
6¾ to 8 (171.4 to 203.2)	0.010 (0.25)	0.010 (0.25)	12.5	12.5

TABLE 11 Outside Diameter Tolerances for Ground Seamless Tubing

NOTE 1—The wall thickness and inside diameter tolerances are the same as for cold-worked mechanical tubing tolerances given in Table Number 8.

Size Outside Diameter, in. (mm)	Outside Diameter Tolerances for Sizes and Lengths Given, in. (mm)			
	Over	Under	Over	Under
	Lengths up to 16 ft (4.9 m), incl		Lengths over 16 ft (4.9 m)	
Up to 1¼ (31.8), incl	0.003 (0.08)	0.000	0.004 (0.10)	0.000
Over 1¼ to 2 (31.8 to 50.8), incl	0.005 (0.13)	0.000	0.006 (0.15)	0.000
	Over	Under	Over	Under
	Lengths up to 12 ft (3.7 m), incl		Lengths to 16 ft (4.9 m)	
Over 2 to 3 (50.8 to 76.2), incl	0.005 (0.13)	0.000	0.006 (0.15)	0.000
Over 3 to 4 (76.2 to 101.6), incl	0.006 (0.15)	0.000	0.008 (0.20)	0.000

identified by a tag or stencil with the manufacturer's name or brand, specified size, grade, purchaser's order number and this specification number (ASTM A 519).

15.2 In addition to the requirements in 15.1 and 15.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

15.3 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for Military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

TABLE 12 Length Tolerances for Round Hot-Finished or Cold-Finished Tubing

NOTE 1—The producer should be consulted for length tolerances for tubes produced by liquid- or air-quenching heat treatment.

Length, ft (m)	Outside Diameter, in. (mm)	Tolerance, in. (mm)	
		Over	Under
4 (1.2) and under	up to 2 (50.8), incl	1/16 (1.6)	0
4 (1.2) and under	over 2 to 4 (50.8 to 101.6), incl	3/32 (2.4)	0
4 (1.2) and under	over 4 (101.6)	1/8 (3.2)	0
Over 4 to 10 (1.2 to 3.0), incl	up to 2 (50.8), incl	3/32 (2.4)	0
Over 4 to 10 (1.2 to 3.0), incl	over 2 (50.8)	1/8 (3.2)	0
Over 10 to 24 (3.0 to 7.3), incl	all sizes	3/16 (4.8)	0
Over 24 (7.3)	all sizes	3/16 + 1/2 (4.8 to 12.7) for each 10 ft (3.0 m) or fraction over 24 ft (7.3 m)	0

16. Packaging

16.1 *Civilian Procurement*—On tubing 0.065 in. (1.65 mm) and lighter, the manufacturer, at his option, will box, crate, carton, package in secured lifts, or bundle to ensure safe delivery. Tubing heavier than 0.065 in. will normally be shipped loose, bundled or in secured lifts. Special packaging requiring extra operations other than those normally used by a manufacturer must be specified in the order.

16.2 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the government when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

17. Keywords

17.1 alloy steel tube; carbon steel tube; mechanical tubing; seamless steel tube; steel tube

TABLE 13 Straightness Tolerances for Seamless Round Mechanical Tubing

NOTE 1—The straightness variation for any 3 ft (0.9 m) of length is determined by measuring the concavity between the tube and a 3-ft straightedge with a feeler gage. The total variation, that is, the maximum curvature at any point in the total length of tube, is determined by rolling the tube on a surface plate and measuring the concavity with a feeler gage.

NOTE 2—The tolerances apply generally to unannealed, finish-annealed, and medium-annealed cold-finished or hot-finished tubes. When straightening stress would interfere with the use of the end product, the straightness tolerances shown do not apply when tubing is specified "not to be straightened after furnace treatment.'' These straightness tolerances do not apply to soft-annealed or quenched and tempered tubes.

Size Limits	Maximum Curvature in any 3 ft/in. (mm/m)	Maximum Curvature in Total Lengths, in. (mm)	Maximum Curvature for Lengths under 3 ft or 1 m
OD 5 in. (127.0 mm) and smaller. Wall thickness, over 3 % of OD	0.030 (0.83)	0.030 × (no. of ft of length/3) (0.83 × no. of m of length)	ratio of 0.010 in./ft or 0.83 mm/m
OD over 5 to 8 in. (127.0 to 203.2 mm), incl. Wall thickness, over 4 % of OD	0.045 (1.25)	0.045 × (no. of ft of length/3) (1.25 × no. of m of length)	ratio of 0.015 in./ft or 1.25 mm/m
OD over 8 to 12¾ in. (203.2 to 323.8 mm), incl. Wall thickness, over 4 % of OD	0.060 (1.67)	0.060 × (no. of ft of length/3) (1.67 × no. of m of length)	ratio of 0.020 in./ft or 16.7 mm/m

TABLE 14 Tolerances for Outside Dimensions and Wall Thickness of Square and Rectangular Cold-Finished Tubing

Largest Outside Dimension across Flats, in. (mm)	Wall Thickness, in. (mm)	Tolerances for Outside Dimensions including Convexity or Concavity	Wall Thickness Tolerance, Plus and Minus, %
To ¾ (19.0), incl	0.065 (1.65) and lighter	±0.015 in. (0.38 mm)	10
To ¾ (19.0), incl	over 0.065 (1.65)	±0.010 in. (0.25 mm)	10
Over ¾ to 1¼ (19.0 to 31.8), incl	all thicknesses	±0.015 in. (0.38 mm)	10
Over 1¼ to 2½ (31.8 to 63.5), incl	all thicknesses	±0.020 in. (0.51 mm)	10
Over 2½ to 3½ (63.5 to 88.9), incl	0.065 (1.65) and lighter	±0.030 in. (0.76 mm)	10
Over 2½ to 3½ (63.5 to 88.9), incl	over 0.065 (1.65)	±0.025 in. (0.64 mm)	10
Over 3½ to 5½ (88.9 to 139.7), incl	all thicknesses	±0.030 in. (0.76 mm)	10
Over 5½ to 7½ (139.7 to 190.5), incl	all thicknesses	±1 %	10

TABLE 15 Corner Radii of Square and Rectangular Cold-Finished Tubing

Wall Thickness, in. (mm)	Maximum Radii of Corners, in. (mm)
Over 0.020 to 0.049 (0.51 to 1.24), incl	3⁄32 (2.4)
Over 0.049 to 0.065 (1.24 to 1.65), incl	1⁄8 (3.2)
Over 0.065 to 0.083 (1.65 to 2.11), incl	9⁄64 (3.6)
Over 0.083 to 0.095 (2.11 to 2.41), incl	3⁄16 (4.8)
Over 0.095 to 0.109 (2.41 to 2.77), incl	13⁄64 (5.2)
Over 0.109 to 0.134 (2.77 to 3.40), incl	7⁄32 (5.6)
Over 0.134 to 0.156 (3.40 to 3.96), incl	1⁄4 (6.4)
Over 0.156 to 0.188 (3.96 to 4.78), incl	9⁄32 (7.1)
Over 0.188 to 0.250 (4.78 to 6.35), incl	11⁄32 (8.7)
Over 0.250 to 0.313 (6.35 to 7.95), incl	7⁄16 (11.1)
Over 0.313 to 0.375 (7.95 to 9.52), incl	1⁄2 (12.7)
Over 0.375 to 0.500 (9.52 to 12.70), incl	11⁄16 (17.5)
Over 0.500 to 0.625 (12.70 to 15.88), incl	27⁄32 (21.4)

TABLE 16 Twist Tolerance of Square and Rectangular Cold-Finished Tubing

NOTE 1—The twist in square and rectangular tubing is measured by holding one end of the tubing on a surface plate and noting the height of either corner of the opposite end of the same side above the surface plate.

Largest Dimension, in. (mm)	Twist Tolerance in 3 ft, in. (mm/m)
Under ½ (12.7)	0.050 (13.8)
½ to 1½ (12.7 to 38.1), incl	0.075 (20.8)
Over 1½ to 2½ (38.1 to 63.5), incl	0.095 (26.2)
Over 2½ to 4 (63.5 to 101.6), incl	0.125 (34.5)

TABLE 17 Length Tolerances When Exact Lengths Are Specified for Square and Rectangular Tubing

Length, ft (m)	Tolerance, in. (mm)	
	Plus	Minus
1 to 4 (0.3 to 1.2), incl	⅛ (3.2)	0
Over 4 to 12 (1.2 to 3.7), incl	3⁄16 (4.8)	0
Over 12 (3.7)	¼ (6.4)	0

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order, and the necessary tests shall be made at the mill. Mechanical tests shall be performed in accordance with the applicable sections of Test Methods and Definitions A 370.

S1. Special Smooth Inside Surface

S1.1 This tubing is intended for use where the inside surface is of prime importance and no stock removal by the user is contemplated. This product differs from conventional mechanical tubing in that special processing or selection, or both, are necessary to obtain the required surface. Light scores and pits within the limits shown in Table S1 are customarily allowable.

S2. Mechanical Requirements

S2.1 *Hardness Test:*

S2.1.1 When hardness limits are required, the manufacturer shall be consulted. Typical hardnesses are listed in Table S2.

S2.1.2 When specified, the hardness test shall be performed on 1 % of the tubes.

S2.2 *Tension Tests:*

S2.2.1 When tensile properties are required, the manufacturer shall be consulted. Typical tensile properties for some of the more common grades and thermal conditions are listed in Table S2.

S2.2.2 When the tension test is specified, one test will be performed on a specimen from one tube per 2000 ft (610 m) or less for sizes over 3 in. (76.2 mm) and one tube per 5000 ft (1520 m) or less for sizes 3 in. (76.2 mm) and under.

S2.2.3 The yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen or to a total extension of 0.5 % of the gage length under load shall be determined.

S2.3 *Nondestructive Tests*—Various types of nondestructive ultrasonic or electromagnetic tests are available. The test to be used and the inspection limits shall be established by manufacturer and purchaser agreement.

S2.4 *Steel Cleanliness*—When there are special requirements for steel cleanliness, the methods of test and limits of acceptance shall be established by manufacturer and purchaser agreement.

S2.5 *Hardenability*—Any requirement for H-steels, tests and test limits shall be specified in the purchase order.

S2.6 *Flaring Test:*

TABLE S1 Special Smooth Finish Tubes Allowance for Surface Imperfections

Size, Outside Diameter, in. (mm)	Wall Thickness, in. (mm)	Wall Depth Allowance for Surface Imperfection, in. (mm)	
		Scores	Pits
⅝ to 2½ (15.8 to 63.5), incl	0.065 to 0.109 (1.65 to 2.77)	0.001 (0.03)	0.0015 (0.038)
	over 0.109 to ¼ (2.77 to 6.4), incl	0.001 (0.03)	0.002 (0.05)
Over 2½ to 5½ (63.5 to 139.7), excl	0.083 to ⅛ (2.11 to 3.2), incl	0.0015 (0.038)	0.0025 (0.064)
	over ⅛ to 3⁄16 (3.2 to 4.8), incl	0.0015 (0.038)	0.003 (0.08)
	over 3⁄16 to ⅜ (4.8 to 9.5), incl	0.002 (0.05)	0.004 (0.10)
5½ to 8 (139.7 to 203.2), excl	⅛ to ¼ (3.2 to 6.4), incl	0.0025 (0.064)	0.005 (0.13)
	over ¼ to ½ (6.4 to 12.7), incl	0.003 (0.08)	0.006 (0.15)

TABLE S2 Typical Tensile Properties, Hardness and Thermal Condition for some of the More Common Grades of Carbon and Alloy Steels

Grade Desig- nation	Condi- tion[A]	Ultimate Strength,		Yield Strength,		Elongation in 2 in. or 50 mm, %	Rockwell, Hardness B Scale
		ksi	MPa	ksi	MPa		
1020	HR	50	345	32	221	25	55
	CW	70	483	60	414	5	75
	SR	65	448	50	345	10	72
	A	48	331	28	193	30	50
	N	55	379	34	234	22	60
1025	HR	55	379	35	241	25	60
	CW	75	517	65	448	5	80
	SR	70	483	55	379	8	75
	A	53	365	30	207	25	57
	N	55	379	36	248	22	60
1035	HR	65	448	40	276	20	72
	CW	85	586	75	517	5	88
	SR	75	517	65	448	8	80
	A	60	414	33	228	25	67
	N	65	448	40	276	20	72
1045	HR	75	517	45	310	15	80
	CW	90	621	80	552	5	90
	SR	80	552	70	483	8	85
	A	65	448	35	241	20	72
	N	75	517	48	331	15	80
1050	HR	80	552	50	345	10	85
	SR	82	565	70	483	6	86
	A	68	469	38	262	18	74
	N	78	538	50	345	12	82
1118	HR	50	345	35	241	25	55
	CW	75	517	60	414	5	80
	SR	70	483	55	379	8	75
	A	50	345	30	207	25	55
	N	55	379	35	241	20	60
1137	HR	70	483	40	276	20	75
	CW	80	552	65	448	5	85
	SR	75	517	60	414	8	80
	A	65	448	35	241	22	72
	N	70	483	43	296	15	75
4130	HR	90	621	70	483	20	89
	SR	105	724	85	586	10	95
	A	75	517	55	379	30	81
	N	90	621	60	414	20	89
4140	HR	120	855	90	621	15	100
	SR	120	855	100	689	10	100
	A	80	552	60	414	25	85
	N	120	855	90	621	20	100

[A] The following are the symbol definitions for the various conditions:
HR—Hot Rolled
CW—Cold Worked
SR—Stress Relieved
A—Annealed
N—Normalized

S2.6.1 When tubing suitable for flaring is required, the manufacturer shall be consulted. When the grade and thermal treatment are suitable for flaring, a section of tube approximately 4 in. (101.6 mm) in length shall stand being flared with a tool having a 60° included angle until the tube at the mouth of the flare has been expanded 15 % of the inside diameter without cracking or showing flaws.

S2.6.2 When the flaring test is specified, tests shall be performed on two specimens/5000 ft (1520 m) or less.

S3. Certification for Government Orders

S3.1 A producer's or supplier's certification shall be furnished to the government that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. This certificate shall include a report of heat analysis (product analysis when requested in the purchase order), and, when specified in the purchase order or contract, a report of test results shall be furnished.

S4. Rejection Provisions for Government Orders

S4.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the tube may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

S4.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such material shall be a matter for agreement.

APPENDIX

(Nonmandatory Information)

X1. MACHINING ALLOWANCES FOR ROUND TUBING

X1.1 Seamless mechanical tubing is produced either hot finished or cold worked. Hot-finished tubes are specified to outside diameter and wall thickness. Cold-worked tubing is specified to two of the three dimensions; outside diameter, inside diameter and wall thickness.

X1.2 There are two basic methods employed in machining such tubing: (*1*) by machining true to the outside diameter of the tube (hereinafter referred to as outside diameter); and (*2*) by machining true to the inside diameter of the tube (hereinafter referred to as inside diameter).

X1.3 For the purpose of determining tube size dimensions, with sufficient allowances for machining, the following four steps are customarily used.

X1.4 *STEP 1*—Step 1 is used to determine the maximum tube outside diameter.

X1.4.1 *Machined Outside Diameter*—Purchaser's maximum blueprint (finish machine) size including plus machine tolerance.

X1.4.2 *Cleanup Allowance*—Sufficient allowance should be made to remove surface imperfections.

X1.4.3 *Decarburization*— Decarburization is an important factor on the higher carbon grades of steel. Decarburization limits are shown in various specifications. For example, the decarburization limits for bearing steels are shown in ASTM specifications, and for aircraft steel in AMS and appropriate government specifications. Decarburization is generally expressed as depth and, therefore, must be doubled to provide for removal from the surface.

X1.4.4 *Camber*—When the machined dimension extends more than 3 in. (76.2 mm) from the chuck or other holding mechanism, the possibility that the tube will be out-of-straight must be taken into consideration. An allowance is made equal to four times the straightness tolerance shown in Table 11 for the machined length when chucked at only one end and equal to twice the straightness tolerance if supported at both ends.

X1.4.5 *Outside Diameter Tolerance*—If machined true to the outside diameter, add the complete spread of tolerance (for example, for specified outside diameter of 3 to 5½ in. (76.2 to 139.7 mm) excl, plus and minus 0.031 in. (0.79 mm) or 0.062 in. (1.55 mm)). If machined true to the inside diameter, outside diameter tolerances are not used in this step. Cold-worked tolerances are shown in Table 8. Hot-finished tolerances are shown in Table 6. The calculated maximum outside diameter is obtained by adding allowances given in X1.4.1 through X1.4.5.

X1.5 *STEP 2*—Step 2 is used to determine the minimum inside diameter.

X1.5.1 *Machined Inside Diameter*—Purchaser's minimum blueprint (finish machine) size including machining tolerance.

X1.5.2 *Cleanup Allowance*—Sufficient allowance should be made to remove surface imperfections.

X1.5.3 *Decarburization*— Decarburization is an important factor on the higher carbon grades of steel. Decarburization limits are shown in various specifications. For example, the decarburization limits for bearing steels are shown in ASTM specifications and for aircraft in AMS and appropriate government specifications. Decarburization is generally expressed as depth and, therefore, must be doubled to provide for removal from the surface.

X1.5.4 *Camber*—Refer to X1.4.4.

X1.5.5 *Inside Diameter Tolerances*—If machined true to the outside diameter, inside diameter tolerances are not used in this step. If machined true to the inside diameter, subtract the complete spread of tolerance (plus and minus). Cold-worked tolerances are shown in Table 8. Hot-finished tolerances (use outside diameter tolerances for inside diameter for calculating purposes) are shown in Table 6. The calculated minimum inside X1 diameter is obtained by subtracting the sum X1.5.2 through X1.5.5 from X1.5.1.

X1.6 *STEP 3*—Step 3 is used to determine the average wall thickness.

X1.6.1 One half the difference between the maximum outside diameter and the minimum inside diameter is considered to be the calculated minimum wall. From the calculated minimum wall, the average is obtained by dividing by 0.90 for cold-worked tubing or 0.875 for hot-finished tubing. This represents the wall tolerance of ±10 % for cold-worked tubing and ±12.5 % for hot-finished tubing. The wall tolerances may be modified in special cases as covered by applicable tables.

X1.7 *STEP 4*—Step 4 is used to determine cold-worked or hot-finished tube size when machined true to either the outside diameter or the inside diameter.

X1.7.1 *Cold-Worked Machined True to Outside Diameter*—Size obtained in Step 1 minus the over tolerance (shown in "Over'' column in Table 8) gives the outside diameter to be specified. The wall thickness to be specified is that determined in Step 3.

X1.7.2 *Cold-Worked Machined True to Inside Diameter*—Size obtained in Step 2 plus twice the calculated wall obtained in Step 3 gives the minimum outside diameter. To find the outside diameter to be specified, add the under part of the tolerance shown in the under outside diameter column in Table 8. The average wall thickness to be specified is that determined in Step 3. If necessary to specify to inside diameter and wall, the under tolerance for inside diameter (shown in Table 8) is added to the inside diameter obtained in Step 2.

X1.7.3 *Hot-Finish Machined True to Outside Diameter*—From the size obtained in Step 1, subtract one half the total tolerance (shown in Table 6) to find the outside diameter to be specified. The average wall thickness to be specified is that determined in Step 3.

X1.7.4 *Hot-Finish Machined True to Inside Diameter*—The average outside diameter to be specified is obtained by adding the under part of the tolerance (shown in the under column of Table 6) to the minimum outside diameter, calculated by adding twice the average wall (from Step 3) to the minimum inside diameter (from Step 2).

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 519 – 03, that may impact the use of this specification. (Approved October 1, 2006)

(*1*) Revised Tables 3 and 4 to agree with composition requirements contained in Guide A 1040.

Designation: A 513 – 07

Standard Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing[1]

This standard is issued under the fixed designation A 513; 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*

1.1 This specification covers electric-resistance-welded carbon and alloy steel tubing for use as mechanical tubing.

1.2 This specification covers mechanical tubing made from hot- or cold-rolled steel.

1.3 This specification covers round, square, rectangular, and special shape tubing.

Type	Size Range (Round Tubing)
Electric-Resistance-Welded Tubing from Hot-Rolled Steel	outside diameter from ½ to 15 in. (19.0 to 381.0 mm) wall from 0.065 to 0.650 in. (1.65 to 16.50 mm)
Electric-Resistance-Welded Tubing from Cold-Rolled Steel	outside diameter from ⅜ to 12 in. (9.92 to 304.8 mm) wall from 0.022 to 0.134 in. (0.71 to 3.40 mm)

1.4 Optional supplementary requirements are provided and when desired, shall be so stated in the order.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 1040 Guide for Specifying Harmonized Standard Grade Compositions for Wrought Carbon, Low-Alloy, and Alloy Steels

E 1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing

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

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

2.2 *ANSI Standard:*

B 46.1 Surface Texture[3]

2.3 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[4]

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[4]

2.4 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[4]

3. Ordering Information

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

3.1.1 Quantity (feet or number of lengths),

3.1.2 Name of material (electric resistance-welded carbon or alloy steel mechanical tubing),

3.1.3 Types, conditions and code letters, (Sections 1 and 12),

3.1.4 Thermal condition, (12.2),

3.1.5 Flash condition, (12.3),

3.1.6 Grade designation, if required, (Section 5),

3.1.7 Report chemical analysis and product analysis, if required (Sections 6 and 7),

3.1.8 Individual supplementary requirements, if required (S1 to S10, inclusive),

3.1.9 Cross section (round, square, rectangular and special shapes),

3.1.10 Dimensions, round, outside and inside and wall thickness (see 8.1 and 8.2) or square and rectangular, outside dimension and wall thickness and corner radii, if required (see 9.1 and 9.2),

3.1.11 Length, round, mill lengths or definite cut length (see 8.3), square and rectangular, specified length (see 9.4),

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved March 1, 2007. Published April 2007. Originally approved in 1964. Last previous edition approved in 2006 as A 513 – 06b.

[2] 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.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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

3.1.12 Squareness of cut, round tubing, if required, (see 8.4),
3.1.13 Burrs removed, if required (see 11.2),
3.1.14 Protective coating (see 14.1),
3.1.15 Special packaging (see 17.1),
3.1.16 Specification designation,
3.1.17 End use,
3.1.18 Special requirements,
3.1.19 Special marking (Section 16), and
3.1.20 Straightness Test Method (see 8.5 and 9.6).

4. Materials and Manufacture

4.1 The steel may be made by any process.

4.2 If a specific type of melting is required by the purchaser, it shall be as stated on the purchase order.

4.3 The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting, such as electroslag or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

4.5 Tubes shall be made by the electric-resistance-welded process and shall be made from hot- or cold-rolled steel as specified.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1 or Table 2 (See Specification A 1040). If no grade is specified, Grades MT 1010 to MT 1020 may be furnished. Analyses of steels other than those listed are available. To determine their availability, the purchaser should contact the producer.

5.2 When a carbon steel grade is 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 Tables 1 and 2 is not permitted.

TABLE 1 Chemical Requirements for Standard Low-Carbon Steels[A]

NOTE 1— Chemistry represents heat analysis. Product analysis, except for rimmed or capped steel, is to be in accordance with usual practice as shown in Table 3.

Grade Designation	Chemical Composition Limits, %			
	Carbon	Manganese	Phosphorus, max	Sulfur, max
MT[B] 1010	0.02–0.15	0.30–0.60	0.035	0.035
MT 1015	0.10–0.20	0.30–0.60	0.035	0.035
MT X 1015	0.10–0.20	0.60–0.90	0.035	0.035
MT 1020	0.15–0.25	0.30–0.60	0.035	0.035
MT X 1020	0.15–0.25	0.70–1.00	0.035	0.035

[A] Rimmed or capped steels which may be used for the above grades are characterized by a lack of uniformity in their chemical composition, and for this reason product analysis is not technologically appropriate unless misapplication is clearly indicated.

[B] The letters MT under grade designation indicate Mechanical Tubing.

6. Heat Analysis

6.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified; if secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The heat analysis shall conform to the requirements specified, except that where the heat identity has not been maintained or where the analysis is not sufficiently complete to permit conformance to be determined, the chemical composition determined from a product analysis made by the tubular manufacturer shall conform to the requirements specified for heat analysis. When requested in the order or contract, a report of such analysis shall be furnished to the purchaser.

7. Product Analysis

7.1 When requested on the purchase order, a product analysis shall be made by the supplier. The number and source of samples for such product analysis shall be based on the individual heat or lot identity of one of the following forms of material:

7.1.1 *Heat Identity Maintained*—One product analysis per heat shall be made on either the flat-rolled stock or tube.

7.1.2 *Heat Identity Not Maintained*—A product from one tube per 2000 ft (610 m) or less for sizes over 3 in. (76.2 mm), and one tube per 5000 ft (150 m) or less for sizes 3 in. and under.

7.2 Samples for product analysis except for spectrochemical analysis shall be taken in accordance with Practice E 1806. The composition thus determined shall correspond to the requirements of Tables 1-3.

7.3 If the original test for product analysis fails, retests of two additional 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 producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

8. Permissible Variations in Dimensions for Round Tubing

8.1 *Diameter and Wall Thickness (Hot-Rolled Steel)*—Variations from specified outside diameter for "as-welded" and "as-welded and annealed" tubing made from hot-rolled steel shall not exceed the amounts prescribed in Table 4. Permissible variations in outside diameter for tubing that has been sink-drawn for closer tolerance on outside diameter are shown in Table 5. Permissible variations in wall thickness for tubing that has been sink-drawn for closer tolerances on outside diameters are ±10 % of the nominal wall or ±0.010 in. (0.25 mm), whichever is greater. Permissible variations in wall thickness for tubing made from hot-rolled steel are shown in Table 6. Permissible variation in outside and inside diameter for tubing made from hot-rolled steel that has been Drawn Over a Mandrel (DOM) for closer tolerances are shown in Table 5 with wall tolerances shown in Table 7.

TABLE 2 Chemical Requirements for Other Carbon and Alloy Steels[A]

NOTE 1—Chemistry represents heat analysis. Product analysis, except for rimmed or capped steel, is to be in accordance with usual practice as shown in Table 3.

Grade Designation	Chemical Composition Limits, %							
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum
1008	0.10 max	0.30–0.50	0.035	0.035	...	...	...	...
1009	0.15 max	0.60 max	0.035	0.035	...	...	...	...
1010	0.08–0.13	0.30–0.60	0.035	0.035	...	...	...	...
1012	0.10–0.15	0.30–0.60	0.035	0.035	...	...	...	...
1015	0.13–0.18	0.30–0.60	0.035	0.035	...	...	...	...
1016	0.13–0.18	0.60–0.90	0.035	0.035	...	...	...	...
1017	0.15–0.20	0.30–0.60	0.035	0.035	...	...	...	...
1018	0.15–0.20	0.60–0.90	0.035	0.035	...	...	...	...
1019	0.15–0.20	0.70–1.00	0.035	0.035	...	...	...	...
1020	0.18–0.23	0.30–0.60	0.035	0.035	...	...	...	...
1021	0.18–0.23	0.60–0.90	0.035	0.035	...	...	...	...
1022	0.18–0.23	0.70–1.00	0.035	0.035	...	...	...	...
1023	0.20–0.25	0.30–0.60	0.035	0.035	...	...	...	...
1024	0.18–0.25	1.30–1.65	0.035	0.035	...	...	...	...
1025	0.22–0.28	0.30–0.60	0.035	0.035	...	...	...	...
1026	0.22–0.28	0.60–0.90	0.035	0.035	...	...	...	...
1027	0.22–0.29	1.20–1.55	0.035	0.035	...	...	...	...
1030	0.28–0.34	0.60–0.90	0.035	0.035	...	...	...	...
1033	0.30–0.36	0.70–1.00	0.035	0.035	...	...	...	...
1035	0.32–0.38	0.60–0.90	0.035	0.035	...	...	...	...
1040	0.37–0.44	0.60–0.90	0.040	0.050	...	...	...	...
1050	0.48–0.55	0.60–0.90	0.040	0.050	...	...	...	...
1060	0.55–0.65	0.60–0.90	0.040	0.050	...	...	...	...
1340	0.38–0.43	1.60–1.90	0.035	0.040	0.15–0.35	...	...	...
1524	0.19–0.25	1.35–1.65	0.040	0.050	...	...	...	...
4118	0.18–0.23	0.70–0.90	0.035	0.040	0.15–0.35	...	0.40–0.60	0.08–0.15
4130	0.28–0.33	0.40–0.60	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
4140	0.38–0.43	0.75–1.00	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
5130	0.28–0.33	0.70–0.90	0.035	0.040	0.15–0.35	...	0.80–1.10	...
8620	0.18–0.23	0.70–0.90	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8630	0.28–0.33	0.70–0.90	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25

[A] Where the ellipsis (...) appears in this table, there is no requirement.

TABLE 3 Tolerances for Product Analysis for Steels Shown in Tables 1 and 2[A,B]

Element	Limit, or Maximum of Specified Range, %	Variation, Over the Maximum Limit or Under the Minimum Limit	
		Under min, %	Over max, %
Carbon	to 0.15, incl	0.02	0.03
	over 0.15 to 0.40, incl	0.03	0.04
	over 0.40 to 0.55, incl	0.03	0.05
Manganese	to 0.60, incl	0.03	0.03
	over 0.60 to 1.15, incl	0.04	0.04
	over 1.15 to 1.65, incl	0.05	0.05
Phosphorus		...	0.01
Sulfur		...	0.01
Silicon	to 0.30, incl	0.02	0.03
	over 0.30 to 0.60	0.05	0.05
Nickel	to 1.00, incl	0.03	0.03
Chromium	to 0.90, incl	0.03	0.03
	over 0.90 to 2.10, incl	0.05	0.05
Molybdenum	to 0.20, incl	0.01	0.01
	over 0.20 to 0.40, incl	0.02	0.02

[A] Individual determinations may vary from the specified heat limits or ranges to the extent shown in this table, except that any element in a heat may not vary both above and below a specified range.
[B] Where the ellipsis (...) appears in this table, there is no requirement.

8.2 *Diameter and Wall Thickness (Cold-Rolled Steel)*—Variations in outside diameter and inside diameter of "as-welded" and "as-welded and annealed" tubing made from cold-rolled steel are shown in Table 8. Outside diameter tolerances for cold-rolled steel tubing, sink drawn and DOM, are shown in Table 5. Wall thickness tolerances for" as-welded" tubing made from cold-rolled steel are shown in Table 9. Permissible variations in wall thickness for round tubing, DOM for closer tolerances, are shown in Table 7. Permissible variations in wall thickness for tubing that has been sink-drawn for closer tolerances on outside diameter are ±10 % of the nominal wall or ±0.010 in. (0.25 mm), whichever is greater.

8.3 *Length (Hot- and Cold-Rolled Steel)*—Mechanical tubing is commonly furnished in mill lengths 5 ft (1.5 m) and over. Definite cut lengths are furnished when specified by the purchaser. Tolerances for definite cut lengths round tubing shall be as given in Tables 10 and 11.

8.4 *Squareness of Cut (Hot- and Cold-Rolled Steel)*—When specified, tolerance for squareness of cut of round tubing shall be as given in Table 12. Measurements are made with use of an "L" square and feeler gage. Side leg of square to be equal to tube diameter except minimum length of 1 in. (25.4 mm) and maximum length of 4 in. (101.6 mm). Outside diameter burr to be removed for measurement.

8.5 *Straightness*— The straightness tolerance for round tubing is 0.030 in./3 ft (0.76 mm/1m) lengths to 8.000 in. (203 mm) outside diameter. For 8.000 in. outside diameter and above, straightness tolerance is 0.060 in./3 ft (1.52 mm/1 m) lengths. For lengths under 1 ft the straightness tolerance shall be agreed upon between the purchaser and producer. The test

TABLE 4 Diameter Tolerances for Type I (A.W.H.R.) Round Tubing

NOTE 1—Measurements for diameter are to be taken at least 2 in.[A] from the ends of the tubes.

Outside Diameter Range, in.[A]	Wall Thickness		Flash-in-Tubing[B,C]	Flash Controlled to 0.010 in. max Tubing[C,D]	Flash Controlled to 0.005 in. max Tubing[E,D]	
	Bwg[F]	in.[A]	Outside Diameter, ±	Outside Diameter, ±	Outside Diameter, ±	Inside Diameter, ±
			Tolerances, in.[A,G]			
½ to 1⅛ , incl	16 to 10	0.065 to 0.134	0.0035	0.0035	0.0035	0.020
Over 1⅛ to 2, incl	16 to 14	0.065 to 0.083	0.005	0.005	0.005	0.021
Over 1⅛ to 2, incl	13 to 7	0.095 to 0.180	0.005	0.005	0.005	0.025
Over 1⅛ to 2, incl	6 to 5	0.203 to 0.220	0.005	0.005	0.005	0.029
Over 1⅛ to 2, incl	4 to 3	0.238 to 0.259	0.005	0.005	0.005	0.039
Over 2 to 2½ , incl	16 to 14	0.065 to 0.083	0.006	0.006	0.006	0.022
Over 2 to 2½ , incl	13 to 5	0.095 to 0.220	0.006	0.006	0.006	0.024
Over 2 to 2½ , incl	4 to 3	0.238 to 0.259	0.006	0.006	0.006	0.040
Over 2½ to 3, incl	16 to 14	0.065 to 0.083	0.008	0.008	0.008	0.024
Over 2½ to 3, incl	13 to 5	0.095 to 0.220	0.008	0.008	0.008	0.026
Over 2½ to 3, incl	4 to 3	0.238 to 0.259	0.008	0.008	0.008	0.040
Over 2½ to 3, incl	2 to 0.320	0.284 to 0.320	0.010	0.010	0.010	0.048
Over 3 to 3½ , incl	16 to 14	0.065 to 0.083	0.009	0.009	0.009	0.025
Over 3 to 3½ , incl	13 to 5	0.095 to 0.220	0.009	0.009	0.009	0.027
Over 3 to 3½ , incl	4 to 3	0.238 to 0.259	0.009	0.009	0.009	0.043
Over 3 to 3½ , incl	2 to 0.360	0.284 to 0.360	0.012	0.012	0.012	0.050
Over 3½ to 4, incl	16 to 14	0.065 to 0.083	0.010	0.010	0.010	0.026
Over 3½ to 4, incl	13 to 5	0.095 to 0.220	0.010	0.010	0.010	0.028
Over 3½ to 4, incl	4 to 3	0.238 to 0.259	0.010	0.010	0.010	0.044
Over 3½ to 4, incl	2 to 0.500	0.284 to 0.500	0.015	0.015	0.015	0.053
Over 4 to 5, incl	16 to 14	0.065 to 0.083	0.020	0.020	0.020	0.036
Over 4 to 5, incl	13 to 5	0.095 to 0.220	0.020	0.020	0.020	0.045
Over 4 to 5, incl	4 to 3	0.238 to 0.259	0.020	0.020	0.020	0.054
Over 4 to 5, incl	2 to 0.500	0.284 to 0.500	0.020	0.020	0.020	0.058
Over 5 to 6, incl	16 to 10	0.065 to 0.134	0.020	0.020	0.020	0.036
Over 5 to 6, incl	9 to 5	0.148 to 0.220	0.020	0.020	0.020	0.040
Over 5 to 6 incl	4 to 3	0.238 to 0.259	0.020	0.020	0.020	0.054
Over 5 to 6, incl	2 to 0.500	0.284 to 0.500	0.020	0.020	0.020	0.058
Over 6 to 8, incl	11 to 10	0.120 to 0.134	0.025	0.025	0.025	0.043
Over 6 to 8, incl	9 to 5	0.148 to 0.220	0.025	0.025	0.025	0.045
Over 6 to 8, incl	4 to 3	0.238 to 0.259	0.025	0.025	0.025	0.059
Over 6 to 8, incl	2 to 0.500	0.284 to 0.500	0.025	0.025	0.025	0.063
Over 8 to 10, incl	14 to 12	0.083 to 0.109	0.030	0.030	0.030	0.041
Over 8 to 10, incl	11 to 10	0.120 to 0.134	0.030	0.030	0.030	0.043
Over 8 to 10, incl	9 to 5	0.148 to 0.220	0.030	0.030	0.030	0.045
Over 8 to 10, incl	4 to 3	0.238 to 0.259	0.030	0.030	0.030	0.059
Over 8 to 10, incl	2 to 0.500	0.248 to 0.500	0.030	0.030	0.030	0.063
Over 10 to 12, incl	14 to 12	0.083 to 0.109	0.035	0.035	0.035	0.041
Over 10 to 12, incl	11 to 10	0.120 to 0.134	0.035	0.035	0.035	0.043
Over 10 to 12, incl	9 to 5	0.148 to 0.220	0.035	0.035	0.035	0.045
Over 10 to 12, incl	4 to 3	0.238 to 0.259	0.035	0.035	0.035	0.059
Over 10 to 12, incl	2 to 0.500	0.284 to 0.500	0.035	0.035	0.035	0.063

[A] 1 in. = 25.4 mm.

[B] Flash-In-Tubing is produced only to outside diameter tolerances and wall thickness tolerances and the inside diameter welding flash does not exceed the wall thickness or 3⁄32 in., whichever is less.

[C] Flash Controlled to 0.010 in. maximum tubing consists of tubing which is commonly produced only to outside diameter tolerances and wall thickness tolerances, in which the height of the remaining welding flash is controlled not to exceed 0.010 in.

[D] No Flash tubing is further processed by DOM for closer tolerances, produced to outside diameter and wall, inside diameter and wall, or outside diameter and inside diameter, with no dimensional indication of inside diameter flash, and is available in Types 5 and 6.

[E] Flash Controlled to 0.005 in. maximum tubing is produced to outside diameters and wall thickness tolerance, inside diameter and wall thickness tolerances, or outside diameters and inside diameter tolerances, in which the height of the remaining flash is controlled not to exceed 0.005 in. Any remaining flash is considered to be part of the applicable inside diameter tolerances.

[F] Birmingham Wire Gage.

[G] The ovality shall be within the above tolerances except when the wall thickness is less than 3 % of the outside diameter, in such cases see 8.6.1.

method for straightness measurement is at the manufacturer's option, unless a specific test method is specified in the purchase order.

8.6 *Ovality (Hot- and Cold-Rolled Steel)*—The ovality shall be within the tolerances except when the wall thickness is less than 3 % of the outside diameter.

TABLE 5 Diameter Tolerances for Types 3, 4, 5, and 6 (S.D.H.R., S.D.C.R., DOM, and S.S.I.D) Round Tubing

NOTE 1—Measurements for diameter are to be taken at least 2 in. from the ends of the tubes.

OD Size Range[A]	Wall % of OD	Types 3, 4, (Sink Drawn)[A,B] and 5, 6, (DOM)[B,C] OD, in.		Types 5 and 6 (DOM)[B,C,] ID in.	
		Over	Under	Over	Under
Up to 0.499	all	0.004	0.000	. . .	. . .
0.500 to 1.699	all	0.005	0.000	0.000	0.005
1.700 to 2.099	all	0.006	0.000	0.000	0.006
2.100 to 2.499	all	0.007	0.000	0.000	0.007
2.500 to 2.899	all	0.008	0.000	0.000	0.008
2.900 to 3.299	all	0.009	0.000	0.000	0.009
3.300 to 3.699	all	0.010	0.000	0.000	0.010
3.700 to 4.099	all	0.011	0.000	0.000	0.011
4.100 to 4.499	all	0.012	0.000	0.000	0.012
4.500 to 4.899	all	0.013	0.000	0.000	0.013
4.900 to 5.299	all	0.014	0.000	0.000	0.014
5.300 to 5.549	all	0.015	0.000	0.000	0.015
5.550 to 5.999	under 6	0.010	0.010	0.010	0.010
	6 and over	0.009	0.009	0.009	0.009
6.000 to 6.499	under 6	0.013	0.013	0.013	0.013
	6 and over	0.010	0.010	0.010	0.010
6.500 to 6.999	under 6	0.015	0.015	0.015	0.015
	6 and over	0.012	0.012	0.012	0.012
7.000 to 7.499	under 6	0.018	0.018	0.018	0.018
	6 and over	0.013	0.013	0.013	0.013
7.500 to 7.999	under 6	0.020	0.020	0.020	0.020
	6 and over	0.015	0.015	0.015	0.015
8.000 to 8.499	under 6	0.023	0.023	0.023	0.023
	6 and over	0.016	0.016	0.016	0.016
8.500 to 8.999	under 6	0.025	0.025	0.025	0.025
	6 and over	0.017	0.017	0.017	0.017
9.000 to 9.499	under 6	0.028	0.028	0.028	0.028
	6 and over	0.019	0.019	0.019	0.019
9.500 to 9.999	under 6	0.030	0.030	0.030	0.030
	6 and over	0.020	0.020	0.020	0.020
10.000 to 10.999	all	0.034	0.034	0.034	0.034
11.000 to 11.999	all	0.035	0.035	0.035	0.035
12.000 to 12.999	all	0.036	0.036	0.036	0.036
13.000 to 13.999	all	0.037	0.037	0.037	0.037
14.000 to 14.999	all	0.038	0.038	0.038	0.038

[A] Tubing, flash in or flash controlled which is further processed without mandrel to obtain tolerances closer than those shown in Tables 4 and 8.

[B] The ovality shall be within the above tolerances except when the wall thickness is less than 3 % of the outside diameter, in such cases see 8.6.2.

[C] Tubing produced to outside diameter and wall thickness, or inside diameter and wall thickness, or outside diameter and inside diameter, by DOM to obtain tolerances closer than those shown in Tables 4 and 8 and no dimensional indication of inside diameter flash.

8.6.1 In such cases for Types 1 and 2 (A.W.H.R. and A.W.C.R.) the ovality may be 50 % greater than the outside tolerances but the mean outside diameter shall be within the specified tolerance.

8.6.2 For Types 3, 4, 5, and 6 (S.D.H.R., S.D.C.R., DOM, and S.S.I.D.) the additional ovality shall be as follows but the mean outside diameter shall be within the specified tolerance:

Outside Diameter, in. (mm)	Additional Ovality Tolerance, in. (mm)
Up to 2 (50.8), incl	0.010 (0.25)
Over 2 to 3 (50.8 to 76.2), incl	0.015 (0.38)
Over 3 to 4 (76.2 to 101.6), incl	0.020 (0.51)
Over 4 to 5 (101.6 to 127.0), incl	0.025 (0.64)
Over 5 to 6 (127.0 to 152.4), incl	0.030 (0.76)
Over 6 to 7 (152.4 to 177.8), incl	0.035 (0.89)
Over 7 to 8 (177.8 to 203.2), incl	0.040 (1.02)
Over 8 to 9 (203.2 to 228.6), incl	0.045 (1.14)
Over 9 to 10 (228.6 to 254.0), incl	0.050 (1.27)
Over 10 to 11 (254.0 to 279.4), incl	0.055 (1.40)
Over 11 to 12 (279.4 to 304.8), incl	0.060 (1.52)
Over 12 to 12.500 (304.8 to 317.5), incl	0.065 (1.65)

9. Permissible Variations in Dimensions of Square and Rectangular Tubing

9.1 *Diameter and Wall Thickness*—Permissible variations in outside dimensions for square and rectangular tubing shall be as given in Table 13. The wall thickness tolerance is ±10 % of the nominal wall thickness.

9.2 *Corner Radii*— Unless otherwise specified, the corners of square and rectangular tubing shall be slightly rounded inside and outside, consistent with wall thickness. The outside corners may be slightly flattened. The radii of corners shall be as given in Table 14.

9.3 *Squareness*—Permissible variations for squareness shall be determined by the following equation:

$$\pm b = c \ x \ 0.006 \text{ in.}$$

where:

b = tolerance for out-of-square, and
c = largest external dimension across flats.

The squareness of sides is commonly determined by one of the following methods.

9.3.1 A square with two adjustable contact points on each arm, is placed on two sides. A fixed feeler gage is then used to measure the maximum distance between the free contact point and the surface of the tubing.

9.3.2 A square equipped with a direct reading vernier, may be used to determine the angular deviation which, in turn, may be related to distance in inches.

9.4 *Length*—Variations from the specified length shall not exceed the amount prescribed in Table 15.

9.5 *Twist*—Twist tolerances are shown in Table 16. The twist in square and rectangular tubing may be measured by holding one end of the tubing on a surface plate and noting the height of either corner of the opposite end of same side above the surface plate. Twist may also be measured by the use of a beveled protractor equipped with a level, and noting the angular deviation on opposite ends, or at any point throughout the length.

TABLE 6 Wall Thickness Tolerance for Type I (A.W.H.R.) Round Tubing

Wall thickness		Outside Diameter, in.^{A}															
		¾ to 1, incl		Over 1 to 1¹⁵⁄₁₆ , incl		Over 1¹⁵⁄₁₆ to 3¾ , incl		Over 3¾ to 4½ , incl		Over 4½ to 6, incl		Over 6 to 8, incl		Over 8 to 10, incl		Over 10 to 12, incl	
in.^{A}	Bwg^{B}	Wall Thickness Tolerances, in., ±^{C}															
		+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−
0.065	16	0.005	0.009	0.004	0.010	0.003	0.011	0.002	0.012	0.002	0.012	0.002	0.012	...	...	...	...
0.072	15	0.005	0.009	0.004	0.010	0.003	0.011	0.002	0.012	0.002	0.012	0.002	0.012	0.003	0.013	...	...
0.083	14	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.095	13	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.109	12	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.120	11	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.134	10	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.148	9	...	...	0.006	0.012	0.005	0.013	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014
0.165	8	...	...	0.006	0.012	0.005	0.013	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014
0.180	7	...	...	0.006	0.012	0.005	0.013	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014
0.203	6	...	...	...	...	0.007	0.015	0.006	0.016	0.005	0.017	0.005	0.017	0.005	0.017	0.005	0.017
0.220	5	...	...	...	...	0.007	0.015	0.006	0.016	0.005	0.017	0.005	0.017	0.005	0.017	0.005	0.017
0.238	4	...	...	...	...	0.012	0.020	0.011	0.021	0.010	0.022	0.010	0.022	0.010	0.022	0.010	0.022
0.259	3	...	...	...	...	0.013	0.021	0.012	0.022	0.011	0.023	0.011	0.023	0.011	0.023	0.011	0.023
0.284	2	...	...	...	...	0.014	0.022	0.013	0.023	0.012	0.024	0.012	0.024	0.012	0.024	0.012	0.024
0.300	1	...	...	...	...	0.015	0.023	0.014	0.024	0.013	0.025	0.013	0.025	0.013	0.025	0.013	0.025
0.320		...	...	...	...	0.016	0.024	0.015	0.025	0.014	0.026	0.014	0.026	0.014	0.026	0.014	0.026
0.344		...	...	...	...	0.017	0.025	0.016	0.026	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027
0.360		...	...	...	...	0.017	0.025	0.016	0.026	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027
0.375		...	...	...	...	...	...	0.016	0.026	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027
0.406		...	...	...	...	...	...	0.017	0.027	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028
0.438		...	...	...	...	...	...	0.017	0.027	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028
0.469		...	...	...	...	...	...	...	...	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028
0.500		...	...	...	...	...	...	...	...	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028

^{A} 1 in. = 25.4 mm.
^{B} Birmingham Wire Gage.
^{C} Where the ellipsis (...) appears in this table, the tolerance is not addressed.

TABLE 7 Wall Thickness Tolerances of Types 5 and 6 (DOM and S.S.I.D.) Round Tubing

Wall Thickness		Outside Diameter, in.[A]							
		⅜ to ⅞, incl		Over ⅞ to 1⅞, incl		Over 1⅞ to 3¾, incl		Over 3¾ to 15, incl	
in.[A]	Bwg[B]	Wall Thickness Tolerances, in.,[A,C] ±							
		+	−	+	−	+	−	+	−
0.035	20	0.002	0.002	0.002	0.002	0.002	0.002	...	...
0.049	18	0.002	0.002	0.002	0.003	0.002	0.003	...	...
0.065	16	0.002	0.002	0.002	0.003	0.002	0.003	0.004	0.004
0.083	14	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.005
0.095	13	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.005
0.109	12	0.002	0.003	0.002	0.004	0.003	0.003	0.005	0.005
0.120	11	0.003	0.003	0.002	0.004	0.003	0.003	0.005	0.005
0.134	10	...	...	0.002	0.004	0.003	0.003	0.005	0.005
0.148	9	...	...	0.002	0.004	0.003	0.003	0.005	0.005
0.165	8	...	...	0.003	0.004	0.003	0.004	0.005	0.006
0.180	7	...	...	0.004	0.004	0.003	0.005	0.006	0.006
0.203	6	...	...	0.004	0.005	0.004	0.005	0.006	0.007
0.220	5	...	...	0.004	0.006	0.004	0.006	0.007	0.007
0.238	4	...	...	0.005	0.006	0.005	0.006	0.007	0.007
0.259	3	...	...	0.005	0.006	0.005	0.006	0.007	0.007
0.284	2	...	...	0.005	0.006	0.005	0.006	0.007	0.007
0.300	1	...	...	0.006	0.006	0.006	0.006	0.008	0.008
0.320		...	...	0.007	0.007	0.007	0.007	0.008	0.008
0.344		...	...	0.008	0.008	0.008	0.008	0.009	0.009
0.375		...	...	...	...	0.009	0.009	0.009	0.009
0.400		...	...	...	...	0.010	0.010	0.010	0.010
0.438		...	...	...	...	0.011	0.011	0.011	0.011
0.460		...	...	...	...	0.012	0.012	0.012	0.012
0.480		...	...	...	...	0.012	0.012	0.012	0.012
0.531		...	...	...	...	0.013	0.013	0.013	0.013
0.563		...	...	...	...	0.013	0.013	0.013	0.013
0.580		...	...	...	...	0.014	0.014	0.014	0.014
0.600		...	...	...	...	0.015	0.015	0.015	0.015
0.625		...	...	...	...	0.016	0.016	0.016	0.016
0.650		...	...	...	0.017	0.017	0.017	0.017	

[A] 1 in. = 25.4 mm.
[B] Birmingham Wire Gage.
[C] Where the ellipsis (...) appears in this table, the tolerance is not addressed.

9.6 *Straightness*— The straightness tolerance is 1⁄16 in./3 ft (1.7 mm/1 m). The test method for straightness measurement is at the manufacturer's option, unless a specific test method is specified in the purchase order.

10. Tubing Sections Other Than Square and Rectangular

10.1 In addition to square and rectangular tubing, many producers supply a variety of special sections, such as oval, streamlined, hexagonal, octagonal, round inside and hexagonal or octagonal outside, ribbed inside or out, triangular, rounded rectangular and D shapes. Manufacturing practices limit the size range and section available from the various producers. These special sections may be made through turkshead rolls or through a die with or without use of a mandrel. Since the sections are special, dies and other tools are not held available. Therefore, when inquiring for shapes other than square and rectangular, it is essential to give full details as to dimensions and finish.

11. Workmanship, Finish, and Appearance

11.1 The tubing shall be free of injurious defects and shall have a workmanlike finish.

11.2 When burrs must be removed from one or both ends, it shall be specified in the purchase order.

12. Types and Conditions

12.1 The types of tubing covered by this specification are:

Type Number	Code Letters	Description
1a	A.W.H.R.	"as-welded" from hot-rolled steel (with mill scale)
1b	A.W.P.O.	"as-welded" from hot-rolled pickled and oiled steel (mill scale removed)
2	A.W.C.R.	"as-welded" from cold-rolled steel
3	S.D.H.R.	"sink-drawn" hot-rolled steel
4	S.D.C.R.	"sink-drawn," cold-rolled steel
5	DOM	Drawn Over a Mandrel
6	S.S.I.D.	special smooth inside diameter

12.2 The thermal conditions under which tubing may be furnished are:

Code	Description
NA	Not Annealed; in the as-welded or as-drawn condition
SRA	Stress Relieved Annealed (at a temperature below the lower critical temperature)
N	Normalized or Annealed (at a temperature above the upper critical temperature)

12.2.1 When the thermal condition is not specified, the tube may be supplied in the NA condition.

12.2.2 When a final thermal treatment is specified, a tight oxide is normal. When an oxide-free surface is specified, the tube may be bright annealed or pickled at the manufacturer's option.

12.3 Flash conditions under which tubing may be furnished are as follows. The flash shall be removed from the outside diameter of tubing covered by this specification. Tubing furnished to this specification may have the following conditions of welding flash on the inside diameter.

12.3.1 *Flash-In*—Tubing in which the inside diameter welding flash does not exceed the wall thickness or 3⁄32 in. (2.4 mm), whichever is less. This condition is available in Types 1a, 1b, 2, 3, and 4.

12.3.2 *Flash Controlled to 0.010 in. (0.25 mm), maximum*—Tubing in which the height of the remaining welding flash is controlled so as not to exceed 0.010 in. This condition is available in Types 1a, 1b, and 2 over 1⅛-in. (28.5-mm) outside diameter and Types 3 and 4.

12.3.3 *Flash Controlled to 0.005 in. (0.13 mm), maximum*—Tubing produced to outside diameter and wall thickness, inside diameter and wall thickness, or outside diameter and inside diameter tolerances which are so controlled that the height of the remaining inside diameter flash does not exceed 0.005 in. Any remaining inside diameter flash is part of the applicable inside diameter tolerance. This condition is available in Types 1a, 1b, 2, 3, and 4.

12.3.4 *No Flash*—Tubing further processed by DOM for closer tolerances, produced to outside diameter and wall thickness, inside diameter and wall thickness, or outside diameter and inside diameter to tolerances, with no dimensional indication of inside diameter flash, is available in Types 5 and 6.

12.4 Tubes shall be furnished in the following shapes, as specified by the purchaser: round, square, rectangular, or special shapes (as negotiated).

TABLE 8 Diameter Tolerances for Type 2 (A.W.C.R.) Round Tubing

NOTE 1—Measurements for diameter are to be taken at least 2 in. from the ends of the tubes.[A]

Outside Diameter Range, in.[A]	Wall Thickness Bwg[A]	Wall Thickness in.[E]	Flash-in-Tubing[B] Outside Diameter, ±	Flash Controlled to 0.010 in. max Tubing[C] Outside Diameter, ±	Flash Controlled[D] to 0.005 in. max Tubing Outside Diameter, ±	Flash Controlled[D] to 0.005 in. max Tubing Inside Diameter, ±
			Tolerances, in.[F,G]			
3⁄8 to 5⁄8 , incl	24 to 16	0.022 to 0.065	0.003	...	...	...
Over 5⁄8 to 11⁄8 , incl	24 to 19	0.022 to 0.042	0.0035	0.0035	0.0035	0.013
Over 5⁄8 to 11⁄8 , incl	18	0.049	0.0035	0.0035	0.0035	0.015
Over 5⁄8 to 11⁄8 , incl	16 to 14	0.065 to 0.083	0.0035	0.0035	0.0035	0.019
Over 3⁄4 to 11⁄8 , incl	13	0.095	0.0035	0.0035	0.0035	0.019
Over 7⁄8 to 11⁄8 , incl	12 to 11	0.109 to 0.120	0.0035	0.0035	0.0035	0.021
Over 11⁄8 to 2, incl	22 to 18	0.028 to 0.049	0.005	0.005	0.005	0.015
Over 11⁄8 to 2, incl	16 to 13	0.065 to 0.095	0.005	0.005	0.005	0.019
Over 11⁄8 to 2, incl	12 to 10	0.109 to 0.134	0.005	0.005	0.005	0.022
Over 2 to 21⁄2 , incl	20 to 18	0.035 to 0.049	0.006	0.006	0.006	0.016
Over 2 to 21⁄2 , incl	16 to 13	0.065 to 0.095	0.006	0.006	0.006	0.020
Over 2 to 21⁄2 , incl	12 to 10	0.109 to 0.134	0.006	0.006	0.006	0.023
Over 21⁄2 to 3, incl	20 to 18	0.035 to 0.049	0.008	0.008	0.008	0.018
Over 21⁄2 to 3, incl	16 to 13	0.065 to 0.095	0.008	0.008	0.008	0.022
Over 21⁄2 to 3, incl	12 to 10	0.109 to 0.134	0.008	0.008	0.008	0.025
Over 3 to 31⁄2 , incl	20 to 18	0.035 to 0.049	0.009	0.009	0.009	0.019
Over 3 to 31⁄2 , incl	16 to 13	0.065 to 0.095	0.009	0.009	0.009	0.023
Over 3 to 31⁄2 , incl	12 to 10	0.109 to 0.134	0.009	0.009	0.009	0.026
Over 31⁄2 to 4, incl	20 to 18	0.035 to 0.049	0.010	0.010	0.010	0.020
Over 31⁄2 to 4, incl	16 to 13	0.065 to 0.095	0.010	0.010	0.010	0.024
Over 31⁄2 to 4, incl	12 to 10	0.109 to 0.134	0.010	0.010	0.010	0.027
Over 4 to 6, incl	16 to 13	0.065 to 0.095	0.020	0.020	0.020	0.034
Over 4 to 6, incl	12 to 10	0.109 to 0.134	0.020	0.020	0.020	0.037
Over 6 to 8, incl	14 to 13	0.083 to 0.095	0.025	0.025	0.025	0.039
Over 6 to 8, incl	12 to 10	0.109 to 0.134	0.025	0.025	0.025	0.042
Over 8 to 10, incl	16 to 13	0.065 to 0.095	0.030	0.030	0.030	0.044
Over 8 to 10, incl	12 to 10	1.109 to 0.134	0.030	0.030	0.030	0.049
Over 10 to 12, incl	14 to 13	0.083 to 0.095	0.035	0.035	0.035	0.049
Over 10 to 12, incl	12 to 10	0.109 to 0.134	0.035	0.035	0.035	0.054

[A] 1 in. = 25.4 mm.
[B] Flash-In-Tubing is produced to outside diameter tolerances and wall thickness tolerances only, and the height of the inside welding flash does not exceed the wall thickness or 3⁄32 in., whichever is less.
[C] Flash Controlled to 0.010 in. maximum tubing consists of tubing over 5⁄8 in. outside diameter which is commonly produced to outside diameter tolerances and wall thickness tolerances only, in which the height of the remaining inside welding flash is controlled not to exceed 0.010 in.
[D] Flash Controlled to 0.005 in. maximum tubing is produced to outside diameter tolerances and wall thickness tolerances, inside diameter tolerances and wall thickness tolerances, or outside diameter tolerances and inside diameter tolerances, in which the height of the remaining inside welding flash is controlled not to exceed 0.005 in. Any remaining flash is considered to be part of the applicable inside diameter tolerances.
[E] Birmingham Wire Gage.
[F] The ovality shall be within the above tolerances except when the wall thickness is less than 3 % of the outside diameter, in such cases see 8.6.1.
[G] Where the ellipsis (...) appears in this table, the tolerance is not addressed.

13. Surface Finish

13.1 Tubes shall have a surface finish compatible with the conditions (Section 12) to which they are ordered (see Appendix X1).

14. Coating

14.1 When specified, tubing shall be coated with a film of oil before shipping to retard rust. Should the order specify that tubing be shipped without rust retarding oil, the film of oils

TABLE 9 Wall Thickness Tolerances for Type 2 (A.W.C.R.) Round Tubing

Wall Thickness		Outside Diameter, in.[A]															
		⅜ to ⅞, incl		Over ⅞ to 1⅞, incl		Over 1⅞ to 3¾, incl		Over 3¾ to 5, incl		Over 5 to 6, incl		Over 6 to 8, incl		Over 8 to 10, incl		Over 10 to 12, incl	
in.[A]	Bwg[B]	Wall Thickness Tolerances, in.,[A,C] ±															
		+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−
0.022	24	0.001	0.005	0.001	0.005	...	...	...	...	...	...	...	...				
0.028	22	0.001	0.005	0.001	0.005	...	...	...	...	...	...	...	...	...	...	...	...
0.035	20	0.002	0.005	0.001	0.005	0.001	0.005	...	...	...	...	...	...	...	...	...	...
0.042	19	0.002	0.006	0.001	0.006	0.001	0.006	...	...	...	...	...	...	...	...	...	...
0.049	18	0.003	0.006	0.002	0.006	0.002	0.006	...	...	...	...	...	...	...	...	...	...
0.065	16	0.005	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007	...	...	0.004	0.008	...	...
0.083	14	0.006	0.007	0.005	0.007	0.004	0.007	0.004	0.007	0.004	0.008	0.004	0.008	0.004	0.008	0.004	0.008
0.095	13	0.006	0.007	0.005	0.007	0.004	0.007	0.004	0.007	0.004	0.008	0.004	0.008	0.004	0.008	0.004	0.008
0.109	12	...	...	0.006	0.008	0.005	0.008	0.005	0.008	0.005	0.009	0.005	0.009	0.005	0.009	0.005	0.009
0.120	11	...	...	0.007	0.008	0.006	0.008	0.005	0.008	0.005	0.009	0.005	0.009	0.005	0.009	0.005	0.009
0.134	10	...	...	0.007	0.008	0.006	0.008	0.005	0.008	0.005	0.009	0.005	0.009	0.005	0.009	0.005	0.009

[A] 1 in. = 25.4 mm.
[B] Birmingham Wire Gage.
[C] Where the ellipsis appears in this table, the tolerance is not addressed.

TABLE 10 Cut-Length Tolerances for Lathe-Cut Round Tubing

Outside Diameter Size, in.[A]	6 in. and under 12 in.	12 in. and under 48 in.	48 in. and under 10 ft	10 ft to 24 ft incl[B]
⅜ to 3 incl	±1⁄64 in.	±1⁄32 in.	±3⁄64 in.	±⅛ in.
Over 3 to 6, incl	±1⁄32 in.	±3⁄64 in.	±1⁄16 in.	±⅛ in.
Over 6 to 9, incl	±1⁄16 in.	±1⁄16 in.	±⅛ in.	±⅛ in.
Over 9 to 12, incl	±3⁄32 in.	±3⁄32 in.	±⅛ in.	±⅛ in.

[A] 1 in. = 25.4 mm.
[B] For each additional 10 ft or fraction thereof over 24 ft, an additional allowance should be made of plus or minus 1⁄16 in.

TABLE 11 Length Tolerances for Punch-, Saw-, or Disc-Cut Round Tubing

Outside Diameter Size, in.[A]	6 in. and under 12 in.	12 in. and under 48 in.	48 in. and under 10 ft	10 ft and 24 ft incl.
⅜ to 3, incl	±1⁄16 in.	±1⁄16 in.	±⅛ in.	±¼ in.
Over 3 to 6, incl	±1⁄16 in.	±1⁄16 in.	±⅛ in.	±¼ in.
Over 6 to 9, incl	±1⁄16 in.	±1⁄16 in.	±⅛ in.	±¼ in.
Over 9 to 12, incl	±1⁄16 in.	±1⁄16 in.	±⅛ in.	±¼ in.

[A] 1 in. = 25.4 mm

TABLE 12 Tolerance (Inch) for Squareness of Cut (Either End) When Specified for Round Tubing[A,B]

Length of Tube, ft[C]	Outside Diameter, in.[D]				
	Under 1	1 to 2, incl	Over 2 to 3, incl	Over 3 to 4, incl	Over 4
Under 1	0.006	0.008	0.010	0.015	0.020
1 to 3, incl	0.008	0.010	0.015	0.020	0.030
Over 3 to 6, incl	0.010	0.015	0.020	0.025	0.040
Over 6 to 9, incl	0.015	0.020	0.025	0.030	0.040

[A] Actual squareness normal to length of tube, not parallelness of both ends.
[B] Values given are "go" value of feeler gage. "no go" value is 0.001 in. greater in each case.
[C] 1 ft = 0.3 m.
[D] 1 in. = 25.4 mm.

incidental to manufacture will remain on the surface. If the order specifies no oil, the purchaser assumes responsibility for rust in transit.

14.2 Special surface preparations as may be required for specific applications are not within the scope of this section. Such requirements shall be considered under the supplementary or basis of purchase provisions of this specification and details shall be provided in the purchase order.

15. Rejection

15.1 Tubes that fail to meet the requirements of this specification shall be set aside and the producer shall be notified.

16. Product and Package Marking

16.1 *Civilian Procurement*—Each box, bundle, lift, or piece shall be identified by a tag or stencil with manufacturers name or brand, specified size, type, purchaser's order number, and this specification number. Bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group [AIAG] standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

16.2 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the Government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for Military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

16.3 *Bar Coding*—In addition to the requirements in 16.1 and 16.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

TABLE 13 Tolerances, Outside Dimensions[A] Square and Rectangular Tubing

Largest Nominal Outside Dimension, in.[B]	Wall Thickness, in.[B]	Outside Tolerance at All Sides at Corners ± in.[B]
3⁄16 to ⅝ , incl	0.020 to 0.083, incl	0.004
Over ⅝ to 1⅛ , incl	0.022 to 0.156, incl	0.005
Over 1⅛ to 1½ , incl	0.025 to 0.192, incl	0.006
Over 1½ to 2, incl	0.032 to 0.192, incl	0.008
Over 2 to 3, incl	0.035 to 0.259, incl	0.010
Over 3 to 4, incl	0.049 to 0.259, incl	0.020
Over 4 to 6, incl	0.065 to 0.259, incl	0.020
Over 6 to 8, incl	0.185 to 0.259, incl	0.025

[A] Measured at corners at least 2 in. from the cut end of the tubing.
Convexity and concavity: Tubes having two parallel sides are also measured in the center of the flat sides for convexity and concavity. This tolerance applies to the specific size determined at the corners, and is measured on the following basis:

Largest Nominal Outside Dimension, in.	Tolerance ±, in.
2½ and under	0.010
Over 2½ to 4	0.015
Over 4 to 8	0.025

[B] 1 in. = 25.4 mm.

17. Packaging

17.1 *Civilian Procurement*—On tubing 16 gage (1.29 mm) and lighter, the producer will determine whether or not the tubing will be boxed, crated, cartoned, packaged in secured lifts, or bundled to ensure safe delivery unless otherwise instructed. Tubing heavier than 16 gage will normally be shipped loose, bundled, or in secured lifts. Special packaging requiring extra operations other than those normally used by a producer must be specified on the order.

17.2 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the Government when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

18. Keywords

18.1 alloy steel tube; carbon steel tube; mechanical tubing; resistance welded steel tube; steel tube; welded steel tube

TABLE 14 Radii of Corners of Electric-Resistance-Welded Square and Rectangular Tubing[A]

Squares and Rectangles Made from Tubes of the Following Diameter Ranges, in.[B]	Wall Thickness in Bwg and in.[B]	Radius Tolerances, in.[C]
½ to 1½ , incl	24 (0.022)	1⁄64 to 3⁄64
½ to 1½ , incl	22 (0.028)	1⁄32 to 1⁄16
½ to 2½ , incl	20 (0.035)	1⁄32 to 1⁄16
½ to 2½ , incl	19 (0.042)	3⁄64 to 5⁄64
½ to 4, incl	18 (0.049)	3⁄64 to 5⁄64
½ to 4⅛ , incl	16 (0.065)	1⁄16 to 7⁄64
¾ to 4⅛ , incl	14 (0.083)	5⁄64 to ⅛
Over 4⅛ to 6, incl	14 (0.083)	3⁄16 to 5⁄16
1 to 4⅛ , incl	13 (0.095)	3⁄32 to 5⁄32
Over 4⅛ to 6, incl	13 (0.095)	3⁄16 to 5⁄16
1¼ to 4, incl	12 (0.109)	⅛ to 13⁄64
Over 4 to 6, incl	12 (0.109)	3⁄16 to 5⁄16
1¼ to 4, incl	11 (0.120)	⅛ to 7⁄32
Over 4 to 6, incl	11 (0.120)	7⁄32 to 7⁄16
2 to 4, incl	10 (0.134)	5⁄32 to 9⁄32
Over 4 to 6, incl	10 (0.134)	7⁄32 to 7⁄16
2 to 4, incl	9 (0.148)	3⁄16 to 5⁄16
Over 4 to 8, incl	9 (0.148)	7⁄32 to 7⁄16
2 to 8, incl	8 (0.165)	¼ to ½
2 to 8, incl	7 (0.180)	¼ to ½
2½ to 4, incl	6 (0.203)	5⁄16 to 9⁄16
Over 4 to 8, incl	6 (0.203)	5⁄16 to 9⁄16
2½ to 8, incl	5 (0.220)	⅜ to ⅝
2½ to 8, incl	4 (0.238)	⅜ to ⅝
2½ to 8, incl	3 (0.259)	⅜ to ⅝

[A] This table establishes a standard radius. The purchaser and producer may negotiate special radii. Slight radius flattening is more pronounced in heavier wall tubing.
[B] 1 in. = 25 mm.
[C] These radius tolerances apply to grades of steel covered in Table 1. The purchaser and producer may negotiate tolerances on other grades of steel.

TABLE 15 Length Tolerances—Square and Rectangular Tubing

Lengths, ft[A]	Tolerances, in.[B]
1 to 3, incl	±1⁄16
Over 3 to 12, incl	±3⁄32
Over 12 to 20, incl	±⅛
Over 20 to 30, incl	±3⁄16
Over 30 to 40, incl	±⅜

[A] 1 ft = 0.3 m.
[B] 1 in. = 25.4 mm.

TABLE 16 Twist Tolerances Electric-Resistance-Welded for Square and Rectangular-Mechanical Tubing

Largest Dimension, in.[A]	Twist Tolerance in 3 ft[B], in.[A]
½ and under	0.032
Over ½ to 1½ , incl	0.050
Over 1½ to 2½ , incl	0.062
Over 2½ to 4, incl	0.075
Over 4 to 6, incl	0.087
Over 6 to 8, incl	0.100

[A] 1 in. = 25.4 mm.
[B] 1 ft = 0.3 m.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order and the necessary tests shall be made at the mill. Mechanical tests shall be performed in accordance with the applicable portions of Test Methods and Definitions A 370.

S1. Tubes for Cylinders

S1.1 Round tubing, DOM for cylinder applications with inside diameter cleanup allowances is considered to be cylinder tubing. Table S1.1 shows the minimum inside diameter allowance for removal of inside surface imperfections by a honing operation.

S2. Cleanup by Centerless Grinding

S2.1 Round tubing, DOM for applications with outside diameter allowances is considered to be special smooth outside surface tubing. Table S2.1 shows the minimum outside diameter stock allowance for removal of outside surface imperfections by centerless grinding.

S3. Cleanup by Machining

S3.1 Cleanup is permitted on round tubing, DOM for applications where machining is required to remove surface imperfections. Table S3.1 shows the minimum stock allowance for removal of surface imperfections from either or both the outside and inside surfaces by machining.

S4. Special Smooth Inside Surface

S4.1 Round tubing, special smooth inside diameter for cylinder applications with microinch finish and inside diameter cleanup allowances is considered to be special smooth inside surface tubing. Table S4.1 shows the maximum average microinch readings on the inside surface. Table S4.2 shows the minimum wall depth allowance for inside surface imperfections.

S5. Hardness and Tensile Requirements

S5.1 When hardness properties are specified on the order, round tubing shall conform to the hardness limits specified in Table S5.1 unless "Tensile Properties Required" is specified in the purchase order. When "Tensile Properties Required" is specified in the purchase order, round tubing shall conform to the tensile requirements and not necessarily the hardness limits shown in Table S5.1. For grades of round tubing not shown in Table S5.1, and for all square and rectangular tubing, tensile or hardness limits shall be upon agreement between the manufacturer and the purchaser.

S5.2 Number of tests and retests shall be as follows: one tension test per lot shall be made (Note S1) and 1 % of all tubes per lot but in no case less than 5 tubes shall be tested for hardness. If the results of the mechanical tests do not conform to the requirements shown in the table, retests shall be made on additional tubes double the original number selected, each of which shall conform to the specified requirements.

NOTE S1—A lot shall consist of all tubes, before cutting to length, of the same size and wall thickness which are produced from the same heat of steel and, when heat treated, subjected to the same finishing treatment in a continuous furnace. When final heat treatment is done in a batch-type furnace, the lot shall include all those tubes which are heat treated in the same furnace charge.

S5.3 The yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen or to a total extension of 0.5 % of the gage length under load shall be determined.

S6. Destructive Weld Tests

S6.1 Round tubing and tubing to be formed into other shapes when in the round form shall meet the following destructive weld tests.

S6.2 *Flattening Test*—A test 4 to 6 in. (101.6 to 152.4 mm) in length shall be flattened between parallel plates with the weld 90 ° from the direction of applied force (at the point of

TABLE S1.1 Minimum Inside Diameter Stock Allowance on Diameter[A] for Removal of Inside-Surface Imperfections by Honing Operation (DOM Tubing)

Outside Diameter, in.[B]	Wall Thickness, in.[B,C]							
	0.065 and under	Over 0.065 to 0.125, incl	Over 0.125 to 0.180, incl	Over 0.180 to 0.230, incl	Over 0.230 to 0.360, incl	Over 0.360 to 0.460, incl	Over 0.460 to 0.563, incl	Over 0.563
Up to and incl 1½	0.010	0.011	0.013	0.015	0.018	...	...	...
Over 1½ to 3 incl	0.010	0.012	0.014	0.016	0.018	0.021	0.023	...
Over 3 to 4 incl	0.011	0.013	0.015	0.017	0.019	0.021	0.023	0.025
Over 4 to 4¾ incl	...	0.014	0.016	0.018	0.020	0.022	0.024	0.026
Over 4¾ to 6 incl	...	0.015	0.017	0.019	0.021	0.023	0.025	0.027
Over 6 to 8 incl	...	0.016	0.018	0.020	0.022	0.024	0.026	0.028
Over 8 to 10½ incl	...	...	...	0.021	0.023	0.025	0.027	0.029
Over 10½ to 12½ incl	...	...	...	0.022	0.024	0.026	0.028	0.030
Over 12½ to 14 incl	...	...	...	0.024	0.025	0.027	0.029	0.031
Over 14 to 15 incl	...	...	...	0.025	0.026	0.028	0.030	0.032

[A] If a specific size is desired, these allowances plus normal size tolerances must be considered in calculating size to be ordered.
[B] 1 in. = 25.4 mm.
[C] Where the ellipsis (...) appears in this table, no allowances have been established.

maximum bending) until opposite walls of the tubing meet. Except as allowed in S6.2.1, no opening in the weld shall take place until the distance between the plates is less than two thirds of the original outside diameter of the tubing. No cracks or breaks in the base metal shall occur until the distance between the plates is less than one third of the original outside diameter of the tubing, but in no case less than five times the thickness of the tubing wall. Evidence of lamination or burnt material shall not develop during the flattening process, and the weld shall not show injurious defects.

S6.2.1 When low D-to-t ratio tubing is tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than 10.

S6.3 *Flaring Test*—A section of tube approximately 4 in. (101.6 mm) in length shall stand being flared with a tool having a 60° included angle until the tube at the mouth of the flare has been expanded 15 % of the inside diameter, without cracking or showing flaws.

S6.4 In order to properly evaluate weld quality, the producer at his option may normalize the test specimen prior to testing.

S6.5 Number of tests and retests: two flattening and two flaring tests shall be made from each lot (Note S1).

TABLE S2.1 Minimum Outside Diameter Stock Allowance on Diameter[A] for Removal of Outside-Surface Imperfections by Centerless Grinding (DOM Tubing)

Outside Diameter, in.[B]	Tubing Wall Thickness, in.[B,C] Up to 0.125, incl	Over 0.125 to 0.180, incl	Over 0.180 to 0.230, incl	Over 0.230 to 0.360, incl	Over 0.360 to 0.460, incl	Over 0.460
Up to 3, incl	0.012	0.014	0.016	0.020	0.024	0.026
Over 3 to 4¾ , incl	0.016	0.018	0.020	0.022	0.024	0.026
Over 4¾ to 6, incl	0.018	0.020	0.022	0.024	0.026	0.028
Over 6 to 7, incl	0.020	0.022	0.024	0.026	0.028	0.030
Over 7 to 8, incl	...	...	0.026	0.027	0.029	0.031
Over 8 to 10½ , incl	...	...	0.027	0.028	0.030	0.032
Over 10½ to 12½ , incl	...	...	0.028	0.030	0.032	0.034
Over 12½ to 14 incl	...	...	0.030	0.032	0.034	0.036
Over 14	...	...	0.033	0.035	0.036	0.037

[A] If a specific size is desired, these allowances plus normal size tolerances must be considered in calculating size to be ordered.
[B] 1 in. = 25.4 mm.
[C] Where the ellipsis (...) appears in this table, no allowances have been established.

TABLE S3.1 Minimum Diameter Stock Allowance for Outside Diameter and Inside Diameter for Removal of Imperfections by Machining (DOM Tubing)[A]

NOTE 1—*Camber*—For every foot or fraction thereof over one foot of length, add 0.010 in.[B] for camber.

Outside Diameter, in.[B]	Wall Thickness, in.[B,C] Up to 0.187	0.187 to 0.230, incl	Over 0.230 to 0.360, incl	Over 0.360 to 0.460, incl	Over 0.460
Up to 1½ incl	0.015	0.020	0.025	...	...
Over 1½ to 3 incl	0.020	0.025	0.030	0.030	0.035
Over 3 to 4¾ incl	0.025	0.030	0.035	0.035	0.040
Over 4¾ to 6 incl	0.030	0.035	0.040	0.040	0.045
Over 6 to 7 incl	0.035	0.040	0.045	0.045	0.050
Over 7 to 8 incl	...	0.045	0.048	0.048	0.053
Over 8 to 10½ incl	...	0.048	0.050	0.050	0.055
Over 10½ to 15 incl	...	0.050	0.055	0.055	0.060

[A] If a specific size is desired, those allowances plus normal size tolerances must be considered in calculating size to be ordered.
[B] 1 in. = 25.4 mm.
[C] Where the ellipsis (...) appears in this table, no allowances have been established.

TABLE S4.1 Maximum Average Microinch Readings on Inside Surface (Special Smooth Inside Diameter Tubing)

Outside Diameter, in.[A]	Tubing Wall Thickness, in.[A,B] 0.065 and Under	Over 0.065 to 0.150, incl	Over 0.150 to 0.187, incl	Over 0.187 to 0.225, incl	Over 0.225 to 0.312, incl
1 to 2½ , incl	40	45	50	55	70
Over 2½ to 4½ , incl	40	50	60	70	80
Over 4½ to 5½ , incl	...	55	70	80	90
Over 5½ to 7, incl	...	55	70	80	90

[A] 1 in. = 25.4 mm.
[B] Where the ellipsis (...) appears in this table, there is no requirement.

TABLE S4.2 Allowance for Surface Imperfections on Inside Diameters of Special Smooth Finish Tubes[A]

Outside Diameter Size, in.[B]	Wall Thickness, in.[B]	Wall Depth Allowance for Inside Diameter Surface Imperfections, in.[B] Scores	Pits
Up to 2½ , incl	0.065 to 0.109, incl	0.001	0.0015
	Over 0.109 to 0.250, incl	0.001	0.002
	Over 0.250 to 0.312, incl	0.001	0.0025
Over 2½ to 5½ , incl	0.083 to 0.125, incl	0.0015	0.0025
	Over 0.125 to 0.187, incl	0.0015	0.003
	Over 0.187 to 0.312, incl	0.002	0.004
Over 5½ to 7, incl	0.125 to 0.187, incl	0.0025	0.005
	Over 0.187 to 0.312, incl	0.003	0.006

[A] If a specific size is desired, these allowances plus normal size tolerances must be considered in calculating size to be ordered.
[B] 1 in. = 25.4 mm.

TABLE S5.1 Hardness Limits and Tensile Properties for Round Tubing

NOTE 1—These values are based on normal mill stress relieving temperatures. For particular applications, properties may be adjusted by negotiation between purchaser and producer.

NOTE 2— For longitudinal strip tests, the width of the gage section shall be 1 in. (25.4 mm) and a deduction of 0.5 percentage points from the basic minimum elongation for each 1⁄32 in. (0.8 mm) decrease in wall thickness under 5⁄16 in. (7.9 mm) in wall thickness shall be permitted.

	Yield Strength, ksi (MPa), min	Ultimate Strength, ksi (MPa), min	Elongation in 2 in. or 50 mm, %, min	RB min	RB max
As-Welded Tubing					
1008	30 (207)	42 (290)	15	50	
1009	30 (207)	42 (290)	15	50	
1010	32 (221)	45 (310)	15	55	
1015	35 (241)	48 (331)	15	58	
1020	38 (262)	52 (359)	12	62	
1021	40 (276)	54 (372)	12	62	
1025	40 (276)	56 (386)	12	65	
1026	45 (310)	62 (427)	12	68	
1030	45 (310)	62 (427)	10	70	
1035	50 (345)	66 (455)	10	75	
1040	50 (345)	66 (645)	10	75	
1340	55 (379)	72 (496)	10	80	
1524	50 (345)	66 (455)	10	75	
4130	55 (379)	72 (496)	10	80	
4140	70 (485)	90 (621)	10	85	
Normalized Tubing					
1008	23 (159)	38 (262)	30		65
1009	23 (159)	38 (262)	30		65
1010	25 (172)	40 (276)	30		65
1015	30 (207)	45 (310)	30		70
1020	35 (241)	50 (345)	25		75
1021	35 (241)	50 (345)	25		78
1025	37 (255)	55 (379)	25		80
1026	40 (276)	60 (414)	25		85
1030	40 (276)	60 (414)	25		85
1035	45 (310)	65 (448)	20		88
1040	45 (310)	65 (448)	20		90
1340	50 (345)	70 (483)	20		100
1524	45 (310)	65 (448)	20		88
4130	50 (345)	70 (483)	20		100
4140	65 (448)	90 (621)	20		105
Sink-Drawn Tubing					
1008	38 (262)	48 (331)	8	65	
1009	38 (262)	48 (331)	8	65	
1010	40 (276)	50 (345)	8	65	
1015	45 (310)	55 (379)	8	67	
1020	50 (345)	60 (414)	8	70	
1021	52 (359)	62 (428)	7	70	
1025	55 (379)	65 (448)	7	72	
1026	55 (379)	70 (483)	7	77	
1030	62 (427)	70 (483)	7	78	
1035	70 (483)	80 (552)	7	82	
DOM Tubing					
1008	50 (345)	60 (414)	5	73	
1009	50 (345)	60 (414)	5	73	
1010	50 (345)	60 (414)	5	73	
1015	55 (379)	65 (448)	5	77	
1020	60 (414)	70 (483)	5	80	
1021	62 (427)	72 (496)	5	80	
1025	65 (448)	75 (517)	5	82	
1026	70 (483)	80 (552)	5	85	
1030	75 (517)	85 (586)	5	87	
1035	80 (552)	90 (621)	5	90	
1040	80 (552)	90 (621)	5	90	
1340	85 (586)	95 (655)	5	90	
1524	80 (552)	90 (621)	5	90	
4130	85 (586)	95 (655)	5	90	
4140	100 (690)	110 (758)	5	90	
DOM Stress-Relieved Tubing					
1008	45 (310)	55 (379)	12	68	

TABLE S5.1 *Continued*

	Yield Strength, ksi (MPa), min	Ultimate Strength, ksi (MPa), min	Elongation in 2 in. or 50 mm, %, min	RB min	RB max
1009	45 (310)	55 (379)	12	68	
1010	45 (310)	55 (379)	12	68	
1015	50 (345)	60 (414)	12	72	
1020	55 (379)	65 (448)	10	75	
1021	58 (400)	68 (469)	10	75	
1025	60 (414)	70 (483)	10	77	
1026	65 (448)	75 (517)	10	80	
1030	70 (483)	80 (552)	10	81	
1035	75 (517)	85 (586)	10	85	
1040	75 (517)	85 (586)	10	85	
1340	80 (552)	90 (621)	10	87	
1524	75 (517)	85 (586)	10	85	
4130	80 (552)	90 (621)	10	87	
4140	95 (655)	105 (724)	10	90	

S7. Hydrostatic Test Round Tubing

S7.1 All tubing will be given a hydrostatic test calculated as follows:

$$P = 2St / D$$

where:
P = hydrostatic test pressure, psi or MPa,
S = allowable fiber stress of 14 000 psi or 96.5 MPa,
t = specified wall thickness, in. or mm, and
D = specified outside diameter, in. or mm.

S8. Nondestructive Electric Test

S8.1 Each tube shall be tested with a nondestructive electric test in accordance with Practice E 213, Practice E 273, Practice E 309, or Practice E 570. It is the intent of this test to reject tubes containing injurious defects.

S8.2 For eddy-current testing, the calibration tube shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection. For welded tubing, they shall be placed in the weld if visible.

S8.2.1 *Drilled Hole*—A hole not larger than 0.031 in. (0.79 mm) in diameter shall be drilled radially and completely through the tube wall, care being taken to avoid distortion of the tube while drilling.

S8.2.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼-in. (6.4-mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the tube. Said notch shall have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. (0.102 mm), whichever is greater.

S8.2.3 *Longitudinal Notch*—A notch 0.031 in. (0.79 mm) or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. (0.102 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

S8.3 For ultrasonic testing, the longitudinal calibration reference notches shall be at the option of the producer, any one of the three common notch shapes shown in Practice E 213 or Practice E 273. The depth of notch shall not exceed 12½ % of the specified wall thickness of the tube or 0.004 in. (0.102 mm), whichever is greater. For welded tubing the notch shall be placed in the weld, if visible.

S8.4 For flux leakage testing, each of the longitudinal calibration notches shall be a straight sided notch not over 12½ % of the wall thickness in depth and not over 1.0 in. (25 mm) in length. Both outside diameter and inside diameter notches shall be placed in the tube located sufficiently apart to enable separation and identification of the signals.

S8.5 Tubing producing a signal equal to or greater than the calibration defect shall be subject to rejection. The area producing the signal may be examined.

S8.5.1 Test signals produced by imperfections which cannot be identified, or produced by cracks or crack-like defects shall result in rejection of the tube subject to rework and retest.

S8.5.2 Test signals produced by imperfections such as those listed below may be judged as injurious or noninjurious depending on visual observation of their severity or the type of signal they produce on the testing equipment used, or both:

S8.5.2.1 Dinges,

S8.5.2.2 Straightener marks,

S8.5.2.3 Loose inside diameter bead and cutting chips,

S8.5.2.4 Scratches,

S8.5.2.5 Steel die stamps,

S8.5.2.6 Chattered flash trim,

S8.5.2.7 Stop marks, or

S8.5.2.8 Tube reducer ripple.

S8.5.3 Any imperfection of the above type exceeding 0.004 in. (0.102 mm) or 12½ % of the specified wall thickness (whichever is greater) in depth shall be considered injurious.

S8.5.3.1 If the imperfection is judged as injurious, the tubes shall be rejected but may be reconditioned and retested providing the dimensional requirements are met.

S8.5.3.2 If the imperfection is explored to the extent that it can be identified as noninjurious, the tubes may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness, after due allowance for cleanup in mandrel drawn tubes.

S9. Certification for Government Orders

S9.1 A producer's or supplier's certification shall be furnished to the Government that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. This certificate shall include a report of heat analysis (product analysis when requested in the purchase order), and when specified in the purchase order or contract, a report of test results shall be furnished.

S10. Rejection Provisions for Government Orders

S10.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the tube may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

S10.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such material shall be a matter for agreement.

APPENDIX

(Nonmandatory Information)

X1. MEASURING MICROINCH FINISH

X1.1 The procedure for making microinch readings on interior surfaces of cold worked tubing (not polished or ground) ½-in. (12.7-mm) inside diameter and larger is as follows:

X1.1.1 Measurements on tubing with longitudinal or no predominant lay should be circumferential on the inside surface of the straight tube, prior to any fabrication, on a plane approximately perpendicular to the tube axis. Measurements on tubing with circumferential lay should be longitudinal.

X1.1.2 Measurements should be made not less than 1 in. (25.4 mm) from the end.

X1.1.3 Measurements should be made at four positions approximately 90° apart or over a complete circumference if the trace should otherwise overlap.

X1.1.4 The length of trace should be in accordance with the latest revision of Section 4.5 of ANSI B 46.1 (not less than 0.600 in. (15.24 mm) long).

X1.1.5 A minimum of three such measurements should be made spaced not less than ¼ in. (6.4 mm) apart along the longitudinal axis.

X1.1.6 The numerical rating shall be the arithmetical average microinch of all readings taken. Each reading to be averaged should be the mean position of the indicator during the trace; any momentary meter excursions occupying less than 10 % of the total trace should be ignored.

X1.1.7 A deviation in numerical rating in various parts of a tube may be expected. Experience to date indicates that a variation of about ±35 % is normal.

X1.2 Instruments should meet the specifications given in the latest revision of ANSI B 46.1.

X1.3 Mechanical tracing is preferred. If hand tracing is used, the speed of trace should not vary by more than ±20 % from the required to give the appropriate cutoff. The 0.030-in. roughness width cutoff should be used.

X1.4 Microinch determinations only refer to roughness of areas that do not contain a defect, injurious or otherwise. Such defects as seams, slivers, pits, laps, etc., are subject to ordinary visual inspection in accordance with applicable specifications or trade customs, and have no relationship to roughness.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 513 – 06b, that may impact the use of this specification. (Approved March 1, 2007)

(*1*) Replaced "mandrel drawn" and "M.D." with DOM throughout the standard.

(*2*) Cleaned up sentence fragments in 12.3.4 and Table 4 notes.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 513 – 06a, that may impact the use of this specification. (Approved December 1, 2006)

(*1*) Revised Table 2 to agree with composition requirements contained in Specification A 1040.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 513 – 06, that may impact the use of this specification. (Approved September 1, 2006)

(*1*) Revised 3.1.3.
(*2*) Deleted old 3.1.11 and renumbered subsequent paragraphs.
(*3*) Deleted old 11.2 and renumbered subsequent paragraphs.
(*4*) Renamed Section 12.
(*5*) Revised 12.1, 12.2, added new 12.2.1 and 12.2.2, and revised 12.3.1, 12.3.2, and 12.3.3.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 513 – 00, that may impact the use of this specification. (Approved May 1, 2006)

(*1*) Revised 5.1.
(*2*) Changed the MT 1010 composition in Table 1
(*3*) Added 1009 in Table 2
(*4*) Added 1009 properties as needed in Table S5.1.

Standard Specification for Cold-Drawn Buttweld Carbon Steel Mechanical Tubing[1]

This standard is issued under the fixed designation A 512; 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*

1.1 This specification covers cold-drawn buttweld carbon steel tubes for use as mechanical tubing.

1.2 This specification covers round, square, rectangular, and special shape mechanical tubing.

1.3 Round tube size ranges covered are outside diameters up to 3 ½ in. (88.9 mm) and wall thickness from 0.035 to 0.500 in. (0.89 to 12.70 mm).

1.4 Optional supplementary requirements are provided and, when desired, shall be so stated in the order.

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 1040 Guide for Specifying Harmonized Standard Grade Compositions for Wrought Carbon, Low-Alloy, and Alloy Steels

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[3]

2.2 *Military Standards:*[4]

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[4]

3. Ordering Information

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

3.1.1 Quantity (feet, weight (Note 1), or number of lengths),

NOTE 1—The term "weight" is temporarily used in this specification because of established trade usage. The word is used to mean both "force" and "mass," and care must be taken to determine which is meant in each case (SI unit for force = newton and for mass = kilogram).

3.1.2 Name of material (buttweld carbon steel mechanical tubing),

3.1.3 Form (round, square, rectangular, special shape),

3.1.4 Condition, description and code letters (Section 5),

3.1.5 Grade, if required (Section 6),

3.1.6 Dimensions (round, Section 9 or square and rectangular, Section 10),

3.1.7 Length (round length, 9.2; square and rectangular length, 10.5),

3.1.8 Burr removal (Section 11),

3.1.9 Report of chemical analysis and products analysis, if required,

3.1.10 Individual supplementary requirements if required (S1 through S5),

3.1.11 Special requirements,

3.1.12 End use,

3.1.13 Specification designation,

3.1.14 Special marking (Section 15), and

3.1.15 Special packaging (Section 16).

4. Materials and Manufacture

4.1 The steel shall be made by any process.

4.2 If a specific type of melting is required by the purchaser, it shall be as stated on the purchase order.

4.3 The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting, such as electroslag or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Oct. 1, 2006. Published October 2006. Originally approved in 1964. Last previous edition approved in 2005 as A 512 – 96 (2005).

[2] 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.

[3] Withdrawn.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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

producer shall remove the transition material by an established procedure that positively separates the grades.

4.5 Tubes shall be made by the furnace buttweld process.

4.6 Tubes shall be cold finished, either externally only (sunk) or externally and internally (mandrel drawn).

5. Condition

5.1 The purchaser shall specify in the order one of the following conditions:

MD (Mandrel Drawn)—No final thermal treatment

SD (Sink Drawn)—No final thermal treatment

MDSR—Mandrel Drawn and Stress Relieved

SDSR—Sink Drawn and Stress Relieved

MDSA—Mandrel Drawn and Soft Annealed or normalized

SDSA—Sink Drawn and Soft Annealed or normalized

NORM-MD-SR—Normalized, Mandrel Drawn, and Stress Relieved

NORM-SD-SR—Normalized, Sink Drawn, and Stress Relieved

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1 or Table 2 (see Specification A 1040) and Table 3.

6.2 When a grade is 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 or Table 2 is not permitted.

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified; if secondary melting processes are used, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The heat analysis shall conform to the requirements specified, except that where the heat identity has not been maintained or where the analysis is not sufficiently complete to permit conformance to be determined, the chemical composition determined from a product analysis made by the tubular manufacturer shall conform to the requirements specified for heat analysis. When requested in the order or contract, a report of such analyses shall be furnished to the purchaser.

7.2 A report of this analysis shall be furnished only when requested on the order.

TABLE 1 Chemical Requirements[A]

Grade Designation		Chemical Composition Limits, %			
		Carbon	Manganese	Phosphorus, max	Sulfur, max
MT	1010	0.05–0.15	0.30–0.60	0.04	0.045
MT	1015	0.10–0.20	0.30–0.60	0.04	0.045
MT X	1015	0.10–0.20	0.60–0.90	0.04	0.045
MT	1020	0.15–0.25	0.30–0.60	0.04	0.045
MT X	1020	0.15–0.25	0.70–1.00	0.04	0.045

[A] Rimmed or capped steels which may be used for the above grades are characterized by a lack of uniformity in their chemical composition, and for this reason product analysis is not technologically appropriate unless misapplication is clearly indicated.

TABLE 2 Chemical Requirements for Other Carbon Grades[A]

Grade Designation[B]	Chemical Composition Limits, %			
	Carbon	Manganese	Phosphorus, max	Sulfur, max
1008	0.10 max	0.30–0.50	0.040	0.045
1010	0.08–0.13	0.30–0.60	0.040	0.045
1012	0.10–0.15	0.30–0.60	0.040	0.045
1015	0.13–0.18	0.30–0.60	0.040	0.045
1016	0.13–0.18	0.60–0.90	0.040	0.045
1018	0.15–0.20	0.60–0.90	0.040	0.045
1019	0.15–0.20	0.70–1.00	0.040	0.045
1020	0.18–0.23	0.30–0.60	0.040	0.045
1021	0.18–0.23	0.60–0.90	0.040	0.045
1025	0.22–0.28	0.30–0.60	0.040	0.045
1026	0.22–0.28	0.60–0.90	0.040	0.045
1030	0.28–0.34	0.60–0.90	0.040	0.045
1035	0.32–0.38	0.60–0.90	0.040	0.045
1110	0.08–0.13	0.30–0.60	0.040	0.130[C]
1115	0.13–0.20	0.60–0.90	0.040	0.130[C]
1117	0.14–0.20	1.00–1.30	0.040	0.130[C]

[A] Rimmed or capped steels which may be used for the above grades are characterized by a lack of uniformity in their chemical composition, and for this reason product analysis is not technologically appropriate unless misapplication is clearly indicated.

[B] Other analyses are available.

[C] Grades 1110, 1115, and 1117 shall contain 0.08 min % sulfur.

TABLE 3 Tolerances for Product Analysis for Steels Shown in Table 1

Element	Limit, or Maximum of Specified Range, %	Variation, Over Maximum Limit or Under Minimum Limit	
		Under min, %	Over max, %
Carbon	To 0.15, incl	0.02	0.03
	Over 01.5	0.03	0.04
Manganeses	To 0.60, incl	0.03	0.03
	Over 0.60	0.04	0.04
Phosphorus	. . .	. . .	0.01
Sulfur	. . .	. . .	0.01

8. Product Analysis

8.1 When requested on the purchase order, a product analysis shall be made by the manufacturer. The chemical composition thus determined shall conform to the requirements prescribed in Table 1 or Table 2 as modified by Table 3.

8.2 The product analysis limits shown for carbon are not normally applicable to the MT grades.

8.3 The number and source of samples for such product analysis shall be based on the individual heat or lot identity of one of the following forms of material.

8.3.1 *Heat Identity Maintained*—One product analysis per heat on either a billet, a length of flat rolled stock, or a tube.

8.3.2 *Heat Identity Not Maintained*—One product analysis from one tube per 2000 ft (610 m) or less for sizes over 3 in. (76.2 mm), or one product analysis from one tube per 5000 ft (1524 m) or less for sizes under 3 in. (76.2 mm).

8.4 If the original test for product analysis fails, retests of 2 additional billets, 2 lengths of flat rolled stock, or 2 tubes shall be made. Both retests for the elements in question shall meet the requirements of this specification; otherwise all remaining material in the heat or lot shall be rejected, or at the option of the producer, each billet, length, flat rolled stock, or tube may be individually tested for acceptance.

8.5 Samples for product analysis, except for spectrochemical analysis, shall be taken in accordance with Practice E 59, and the composition thus determined shall correspond to the requirements in applicable section or table.

9. Permissible Variations in Dimensions of Round Tubing

9.1 *Diameter and Wall Thickness*:

9.1.1 Variations in outside diameter, inside diameter, and wall thickness shall not exceed the amounts prescribed in Table 4.

9.1.2 These variations apply to round, unannealed, and stress-relieved tubing.

9.1.3 Diameter tolerance includes ovality.

9.1.4 Sink tubing is normally ordered by outside diameter and nominal wall. Mandrel-drawn tubing is normally ordered by outside diameter and inside diameter and may be ordered by outside diameter or inside diameter and wall thickness but not by all three dimensions.

9.2 *Length*—Random lengths between acceptable limits will be furnished, utilizing the full mill length. Tubing will be cut in half if specified. Full length random tubing will have a spread not exceeding 7 ft (2.1 m). Half-length random tubing will have a spread not exceeding 4 ft (1.2 m). Not more than 10 % of the total footage of a shipment may be furnished in lengths shorter than the minimum specified but not less than 6 ft (1.8 m).

9.2.1 When specified, multiple lengths will be furnished and should include allowances made for the customer's cutting tool width and grippage. Maximum and minimum lengths may be specified with the understanding that not more than 10 % of the total footage in a shipment may be furnished in individual multiples cut to the customer's specifications.

9.2.2 Variations from the specified length shall not exceed the amounts prescribed in Table 5.

9.3 *Straightness*:

9.3.1 A round tube shall be considered straight provided that no 3-ft (0.9-m) section departs from a straight line by more than 0.030 in. (0.76 mm).

9.3.2 The straightness of round tubes shorter than 3 ft (0.9 m) shall be proportionate to 0.010 in./ft (0.8 mm/m).

9.3.3 These straightness tolerances do not apply to soft-annealed tubing nor to long lengths of small diameter tubing.

TABLE 5 Permissible Variations in Length—Round Tubing

Lengths 4 ft (1.2 m) and under—up to 2 in. (50.8 mm) diameter	± 1⁄32 in. (0.8 mm)
Lengths 4 ft (1.2 m) and under—over 2 in. (50.8 mm) diameter	±3⁄64 in. (1.2 mm)
Lengths 4 ft to 10 ft (1.2 to 3.0 m), incl—up to 2 in. (50.8 mm) diameter	±3⁄64 in. (1.2 mm)
Lengths 4 ft to 10 ft (1.2 to 3.0 m), incl—over 2 in. (50.8 mm) diameter	±1⁄16 in. (1.6 mm)
Lengths 10 ft to 24 ft (3.0 to 7.3 m), incl—all diameters	±1⁄8 in. (3.2 mm)
Lengths over 24 ft (7.3 m)—all diameters	±1⁄8 in. (3.2 mm)[A]

[A] Plus an additional tolerance of ±1⁄16 (1.6 mm) for each 10 ft (3.0 m) or fraction over 24 ft (7.3 m).

10. Permissible Variations in Dimensions of Square and Rectangular Tubing

10.1 *Outside Dimensions and Wall Thickness*—Variations in largest outside dimensions across flats and wall thickness shall not exceed the amounts prescribed in Table 6.

10.2 *Corner Radii*—The corners of square and rectangular tubes shall be slightly rounded inside and slightly rounded outside consistent with wall thickness. The outside corners may be slightly flattened. The radii of corners for square and rectangular cold-finished buttweld tubes shall be in accordance with Table 7. Special radii may be obtained.

10.3 *Squareness Tolerance*—Permissible variations for the side of square and rectangular tube shall be determined by the following equation:

$$\pm b = c \times 0.006, \text{ in. (mm)}$$

where:
b = tolerance for out-of-square, and
c = largest external dimensions across flats, in. (mm).

The squareness of sides is commonly determined by one of the following methods:

10.3.1 A square, with two adjustable contact points on each arm, is placed on two sides. A fixed feeler gage is then used to measure the maximum distance between the free contact point and the surface of the tubing.

TABLE 4 Diameter and Wall Thickness Tolerances for Round Tubing

Outside Diameter Range, in. (mm)	Outside Diameter, in. (mm)		Inside Diameter, in. (mm)		Wall Thickness, %	
	Over	Under	Over	Under	Over	Under
Sunk						
Up to 1⁄2 (12.7), excl	0.004 (0.10)	0	. . .	. . .	15[A]	15
1⁄2 to 11⁄2 (12.7 to 38.1), excl	0.005 (0.13)	0	. . .	. . .	10[A]	10
11⁄2 to 3 (38.1 to 76.2), incl	0.010 (0.25)	0	. . .	. . .	10[A]	10
Mandrel Drawn						
Less than 0.156 (3.96) wall:						
Up to 1⁄2 (12.7), excl	0.004 (0.10)	0	0	0.010 (0.25)	121⁄2	121⁄2
1⁄2 to 11⁄2 (12.7 to 38.1), excl	0.005 (0.13)	0	0	0.005 (0.13)[B]	10	10
0.156 (3.96) wall and over:						
1⁄2 to 11⁄2 (12.7 to 38.1), excl	0.005 (0.13)	0	0	0.005 (0.13)[B]	7	7
Under 0.156 (3.96) wall:						
11⁄2 (38.1) and over	0.010 (0.25)	0	. . .	0.010 (0.25)	10	10
0.156 (3.96) wall and over:						
11⁄2 (38.1) and over	0.010 (0.25)	0	0	0.010 (0.25)	7	7

[A] Except at the weld line, where the weld pad may exceed this figure.
[B] Tubes with an inside diameter under 1⁄2 in. (12.7 mm) may require more than 0.005 in. (0.13 mm) inside diameter tolerance and the producer should be consulted.

TABLE 6 Outside Dimension and Wall Thickness Tolerances for Square and Rectangular Tubing

Largest Outside Dimension Across Flats	Wall Thickness	Outside Dimension, Including Convexity or Concavity		Wall Thickness Tolerance, ±, %	
		Over	Under	Sink[A]	Mandrel
Inch-Pound Units					
in.	in.	in.	in.		
To ¾	over 0.065	0.010	0.010	15	12½
Over ¾ to 1¼	under 0.156	0.015	0.015	10	10
Over ¾ to 1¼	0.156 and over	0.015	0.015	10	7
Over 1¼ to 2½	under 0.156	0.020	0.020	10	10
Over 1¼ to 2½	0.156 and over	0.020	0.020	10	7
SI Units					
mm	mm	mm	mm		
To 19.0	over 1.65	0.25	0.25	15	12½
Over 19.0 to 31.8	under 3.96	0.38	0.38	10	10
Over 19.0 to 31.8	3.96 and over	0.38	0.38	10	7
Over 31.8 to 63.5	under 3.96	0.51	0.51	10	10
Over 31.8 to 63.5	3.96 and over	0.51	0.51	10	7

[A] Except at the weld line where the weld pad may exceed this figure.

TABLE 7 Radii of Corners of Butt-Weld Square and Rectangular Tubing

Wall Thickness, in. (mm)	Maximum Radii of Corners, in. (mm)[A]
0.065 to 0.083 (1.65 to 2.11), incl	9⁄64 (3.6)
Over 0.083 to 0.095 (2.11 to 2.41), incl	3⁄16 (4.8)
Over 0.095 to 0.109 (2.41 to 2.76), incl	13⁄64 (5.2)
Over 0.109 to 0.134 (2.76 to 3.40), incl	7⁄32 (5.6)
Over 0.134 to 0.156 (3.40 to 3.96), incl	¼ (6.4)
Over 0.156 to 0.188 (3.96 to 4.78), incl	9⁄32 (7.1)
Over 0.188 to 0.250 (4.78 to 6.35), incl	11⁄32 (8.7)
Over 0.250 to 0.313 (6.35 to 7.95), incl	7⁄16 (11.1)
Over 0.313 to 0.375 (7.95 to 9.52), incl	½ (12.7)
Over 0.375 to 0.500 (9.52 to 12.70), incl	11⁄16 (17.5)

[A] These tolerances apply to grades MT 1010 and MT 1015 steel only. Tolerances on other grades shall be established between the manufacturer and the purchaser.

10.3.2 A square, equipped with direct-reading vernier, may be used to determine the angular deviation which, in turn, may be related to distance to inches.

10.4 *Twist Tolerance*—Variation in twist for square and rectangular tubing shall not exceed the amounts prescribed in Table 8. The twist in square and rectangular tubing may be measured by holding one end of the tubing on a surface plate and noting the height of either corner of the opposite end of same side above the surface plate. Twist may also be measured by means of a beveled protractor equipped with a level. The angular deviation is measured on opposite ends or at any point throughout the length.

10.5 *Length*—Random lengths between acceptable limits will be furnished, utilizing the full mill length. Tubing will be cut in half if specified. Full length random tubing will have a spread not exceeding 7 ft (2.1 m). Half-length random tubing will have a spread not exceeding 4 ft (1.2 m). Not more than 10 % of the total footage of a shipment may be furnished in lengths shorter than the minimum specified, but not less than 6 ft (1.8 m).

10.5.1 When specified, multiple lengths will be furnished and should include allowances made for the customer's cutting tool width and grippage. Maximum and minimum lengths may be specified with the understanding that not more than 10 % of the total footage in a shipment may be furnished in individual multiples cut to the customer's specifications.

10.5.2 Variations from the specified length shall not exceed the amounts prescribed in Table 9.

10.6 *Straightness*—The straightness tolerance for square and rectangular tubing shall be 1⁄16 in. in 3 ft (1:576).

11. Workmanship, Finish, and Appearance

11.1 Tubes shall have a surface finish compatible with the conditions (Section 5) to which the tubes are ordered.

11.2 Special surface preparations as may be required for specific applications are not within the scope of this section. Such requirements shall be considered under the supplementary or basis of purchase provisions of this specification, and details shall be provided in the purchase order.

11.3 The tubing shall be free of injurious defects and shall have a workmanlike finish. Surface imperfections such as handling marks, straightening marks, light die marks, or shallow pits are not considered injurious.

11.4 The tubing shall be free of scale. In the case of thermally treated tubing, a slight amount of color will not be considered cause for rejection.

TABLE 8 Twist Tolerance, Square and Rectangular Mechanical Tubing

Largest Dimension, in. (mm)	Twist Tolerance in 3 ft, in. (in 1 m, mm)
Under ½ (12.7)	0.050 (0.014)
½ to 1½ (12.7 to 38.1), incl	0.075 (0.020)
Over 1½ to 2½ (38.1 to 63.5), incl	0.095 (0.026)
Over 2½ (63.5)	0.125 (0.035)

TABLE 9 Permissible Variation in Length—Square and Rectangular Tubing

Lengths 3 ft (0.9 m) and under	±1⁄16 in. (1.,6 mm)
Lengths over 3 to 12 ft (0.9 to 3.7 m), incl	±3⁄32 in. (2.4 mm)
Lengths over 12 to 20 ft (3.7 to 6.1 m), incl	±⅛ in. (3.2 mm)
Lengths over 20 to 30 ft (6.1 to 9.1 m), incl	±3⁄16 in. (4.8 mm)
Lengths over 30 to 40 ft (9.1 to 12.2 m), incl	±⅜ in. (9.5 mm)

11.5 Saw cut tubes will be furnished without removing outside diameter and inside diameter burrs.

11.6 Lathe cut tubes will be furnished with outside diameter burr only removed.

11.7 Burr removal may be obtained by so specifying in the purchase order.

12. Machining Allowance—Round Tubing

12.1 For the method of calculating the tube size required to clean up machining to a particular finished part, see Appendix X1.

13. Coating

13.1 Unless otherwise specified, the outside surface of the tubing shall be coated, before shipping, with a film of rust-retarding oil. Unless otherwise specified, the inside surface of the tubing may also be coated with a film of rust-retarding oil at the option of the manufacturer. When the order specifies that the tubing be shipped without rust-retarding oil, the film of oils incidental to manufacturing will remain on the surfaces. If the order specifies no oil, the purchaser assumes responsibility for rust in transit.

14. Rejection

14.1 Tubes that fail to meet the requirements of the specification shall be set aside, and the manufacturer shall be notified.

15. Product Marking

15.1 *Civilian Procurement*—Each box, bundle, lift, or, when individual pieces are shipped, each piece shall be identified by a tag or stencil with the manufacturer's name or brand, grade or material, purchaser's order number, and this specification number (ASTM designation).

15.2 *Bar Coding*—In addition to the requirements in 15.1 and 15.3 bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

15.3 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for Military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

16. Packaging

16.1 *Civilian Procurement*—The manufacturer, at his option, will box, crate, carton, package in secured lifts, or bundle to ensure safe delivery. Special packaging requiring extra operations other than those normally used by the manufacturer must be specified on the order.

16.2 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the government when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

17. Keywords

17.1 carbon steel tube; mechanical tubing; steel tube

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order, and the necessary tests shall be made at the mill. Mechanical property tests shall be performed in accordance with applicable portions of Test Methods and Definitions A 370.

S1. Hardness and Tension Tests—Round Tubing

S1.1 When hardness is specified in the order, the tubing shall conform to the hardness limits specified in Table S1.1 or Table S1.2, unless "Tensile Properties Required" is specified in the purchase order. When "Tensile Properties Required" is specified in the purchase order, the tubing shall conform to the tension test requirements and not necessarily the hardness limits shown in Table S1.1 or Table S1.2.

TABLE S1.1 Tensile and Hardness Requirements for Stress Relief Annealed Round Tubes

Grade	Tensile Strength, ksi (MPa)		(0.2 % Offset) Yield Strength, min, ksi (MPa)	Elongation in 2 in. or 50 mm, min, %	Rockwell Hardness	
	min	max			min	max
MT1010	63 (434)	100 (689)	58 (400)	15	B 70	B 90
1011	65 (448)	100 (689)	59 (407)	13	B 70	B 100
MT1015	66 (555)	100 (689)	60 (414)	14	B 70	B 100
1016	67 (462)	100 (689)	61 (421)	13	B 70	B 100
MT1017	67 (462)	100 (689)	62 (427)	13	B 72	B 100
1018	68 (469)	100 (689)	62 (427)	13	B 73	B 100
MT1020	71 (490)	130 (896)	65 (448)	11	B 75	C 20
1025	72 (496)	130 (896)	67 (462)	11	B 78	C 20
1030	80 (552)	130 (896)	70 (483)	10	B 80	C 20
1110	63 (434)	100 (689)	58 (400)	15	B 70	B 100
1115	68 (469)	100 (689)	62 (427)	13	B 70	B 100

TABLE S1.2 Tensile and Hardness Requirements for Soft Annealed Round Tubes

Grade	Tensile Strength, min, ksi (MPa)	Yield Strength, min, ksi (MPa)	Elongation in 2 in. or 50 mm, min, %	Rockwell Hardness
MT1010	40 (276)	20 (138)	35	B 40 to B 65
MT1015	43 (296)	25 (172)	34	B 40 min
MT1020	50 (345)	30 (207)	32	B 50 min
MT1025	55 (379)	35 (241)	32	B 55 min
MT1030	65 (448)	40 (276)	30	B 60 min

S1.2 *Number of Tests and Retests:*

S1.2.1 *Hardness*—One percent of all tubes per lot (Note S1.1),

S1.2.2 *Tension:*

S1.2.2.1 One test per lot (Note S1.1).

S1.2.2.2 The yield strength corresponding to a permanent offset of 0.2 % of the gauge length of the specimen or to a total extension of 0.5 % of the gauge length under load shall be determined.

S1.2.3 If the results of the mechanical tests do not conform to the requirements shown in Table S1.1 and Table S1.2, retests shall be made on additional tubes double the original number, each of which shall conform to the specified requirements.

NOTE S1.1—A lot shall consist of all tubes, before cutting to length, of the same size and wall thickness which are produced from the same heat of steel and, when heat treated, subjected to the same finishing treatment in a continuous furnace. When final heat treatment is in a batch-type furnace, the lot shall include only those tubes which are heat treated in the same furnace charge.

S2. Flattening Test—Soft-Annealed Round Tubing

S2.1 The weld shall be located 45° from the line of the direction of applied force. No cracks other than superficial surface ruptures shall appear in the weld until the distance between the flattening plates is less than three fourths of the outside diameter of the tube. Likewise, no cracks, other than superficial surface ruptures, shall appear in the metal of the tube other than the weld metal until the distance between the flattening plates is less than three fifths of the outside diameter of the tube.

S2.2 *Number of Tests and Retests:*

S2.2.1 One test per lot (Note S1.1).

S2.2.2 Two retests per lot (Note S1.1).

S3. Flaring Test—Round Tubing

S3.1 A tapered mandrel having a slope of 1 in 10 shall be driven into one end of a soft-annealed section cut to a suitable length and thus expanding the specimen until the outside diameter has been increased 5 %.

S3.2 *Number of Tests and Retests:*

S3.2.1 One test per lot (Note S1.1).

S3.2.2 Two retests per lot (Note S1.1).

S4. Nondestructive Electrical Test—Round Tubing

S4.1 The manufacturer shall test the tubing by an electrical method of nondestructive test for detection of harmful faults and soundness of weld. The equipment used shall be capable of indicating and rejecting all defects on the outside diameter or inside diameter greater than 1⁄16 in. (1.6 mm) in length and to a depth greater than approximately one fourth the wall thickness.

S5. Certification for Government Orders

S5.1 A producer's or supplier's certification shall be furnished to the Government that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. This certificate shall include a report of heat analysis (product analysis when requested in the purchase order), and, when specified in the purchase order or contract, a report of test results shall be furnished.

APPENDIX

(Nonmandatory Information)

X1. MACHINING ALLOWANCES

X1.1 The minimum diameter stock allowance for removal of imperfections by machining from the outside of the tube when chucked concentrically on the tube outside diameter is given in Table X1.1.

X1.2 *Boring Mandrel Drawn Tubing*—When chucked concentrically with the outside diameter, mandrel drawn tubing will clean up concentrically with the outside diameter on a boring operation at a size derived from the following equation:

Ordered inside diameter = finished inside diameter − (0.075 in. (1.90 mm) × original outside diameter − amount shown in Table X1.1).

TABLE X1.1 Machining Allowances[A]

NOTE—1 in. = 25.4 mm.

Diameter, in.	Wall Thickness, in. Up to 0.200	Wall Thickness, in. 0.200 and Over
Sink Drawn:		
Up to 1½	0.025	0.030
1½ and over	0.030	0.035
Mandrel Drawn:		
Up to 1½	0.020	0.025
1½ and over	0.025	0.030

[A] If a specific size is desired, these allowances plus normal size tolerances must be considered in calculating the size to be ordered.

X1.2.1 To this equation, add 0.005 in. (0.13 mm) when the original outside diameter does not exceed 1 ½ in. (38.1 mm); add 0.010 in. (0.25 mm) when the original outside diameter is over 1 ½ in. These equations apply to tubes chucked within 2 in. (50.8 mm) of the end being bored.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 512 – 96(2005), that may impact the use of this specification. (Approved October 1, 2006)

(*1*) Revised Table 2 to agree with composition requirements contained in Specification A 1040.

Designation: A 511 – 04

Standard Specification for Seamless Stainless Steel Mechanical Tubing[1]

This standard is issued under the fixed designation A 511; 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*

1.1 This specification covers seamless stainless tubing for use in mechanical applications where corrosion-resistant or high-temperature strength is needed. The grades covered are listed in Table 1 and Table 2.

1.2 This specification covers seamless cold-finished mechanical tubing and seamless hot-finished mechanical tubing in sizes up to 12¾ in. (313.8 mm) in outside diameter (for round tubing) with wall thicknesses as required.

1.3 Tubes shall be furnished in one of the following shapes, as specified by the purchaser: round, square, rectangular, or special.

1.4 Optional supplementary requirements are provided and when desired, shall be stated in the order.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

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 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition

2.2 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[3]

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[3]

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[3]

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, mass, or number of pieces),

3.1.2 Name of material (seamless stainless steel mechanical tubing),

3.1.3 Form (round, square, rectangular, special, see Section 1),

3.1.4 Dimensions (round, outside diameter and wall thickness, see Section 9; square and rectangular, outside dimensions and wall thickness, see Section 10; other, specify),

3.1.5 Length (specific or random, see 9.3),

3.1.6 Manufacture (cold- or hot-finished, see 4.5),

3.1.7 Grade (Section 6),

3.1.8 Condition (annealed, as cold worked, or with special heat treatment, controlled microstructural characteristics, or other condition as required, see Section 5),

3.1.9 Surface finish (special pickling, shot blasting, or polishing, as required, see Supplementary Requirement S5),

3.1.10 Specification designation,

3.1.11 Report of Chemical Analysis, if required (Sections 7 and 8),

3.1.12 Individual supplementary requirements, if required,

3.1.13 End use,

3.1.14 Packaging,

3.1.15 Special marking (see 15.2),

3.1.16 Special packing (see 16.2), and

3.1.17 Special requirements.

4. Materials and Manufacture

4.1 The steel may be made by any process.

4.2 If a specific type of melting is required by the purchaser, it shall be as stated on the purchase order.

4.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, such as electroslag remelting or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

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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 Tubing.

Current edition approved March 1, 2004. Published April 2004. Originally approved in 1964. Last previous edition approved in 1996 as A 511 – 96.

[2] 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.

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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

TABLE 1 Chemical Requirements of Austenitic Stainless Steels

Grade	Composition, %									
	Carbon	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Titanium	Columbium plus Tantalum	Selenium
MT 302	0.08 to 0.20	2.00	0.040	0.030	1.00	8.0–10.0	17.0–19.0	...	...	...	...
MT 303Se	0.15 max	2.00	0.040	0.040	1.00	8.0–11.0	17.0–19.0	...	...	...	0.12–0.2
MT 304	0.08 max	2.00	0.040	0.030	1.00	8.0–11.0	18.0–20.0	...	...	...	...
MT 304L	0.035 max[A]	2.00	0.040	0.030	1.00	8.0–13.0	18.0–20.0	...	...	...	...
MT 305	0.12	2.00	0.040	0.030	1.00	10.0–13.0	17.0–19.0	...	...	...	...
MT 309S	0.08 max	2.00	0.040	0.030	1.00	12.0–15.0	22.0–24.0	...	...	...	...
MT 310S	0.08 max	2.00	0.040	0.030	1.00	19.0–22.0	24.0–26.0	...	...	...	...
MT 316	0.08 max	2.00	0.040	0.030	1.00	11.0–14.0	16.0–18.0	2.0–3.0	...	...	...
MT 316L	0.035 max[A]	2.00	0.040	0.030	1.00	10.0–15.0	16.0–18.0	2.0–3.0	...	...	...
MT 317	0.08 max	2.00	0.040	0.030	1.00	11.0–14.0	18.0–20.0	3.0–4.0	...	...	...
MT 321	0.08 max	2.00	0.040	0.030	1.00	9.0–13.0	17.0–20.0	...	[B]	...	...
MT 347	0.08 max	2.00	0.040	0.030	1.00	9.0–13.0	17.0–20.0	...	...	[C]	...

[A]For small diameter or thin wall tubing or both, where many drawing passes are required, a maximum of 0.040 % carbon is necessary in grades MT-304L and MT-316L. Small outside diameter tubes are defined as those under a 0.500 in. outside diameter and light-wall tubes as those under an 0.049 in. average wall thickness (0.044 in. min wall thickness).

[B]The titanium content shall be not less than five times the carbon content and not more than 0.60 %.

[C]The columbium plus tantalum content shall be not less than ten times the carbon content and not more than 1.00 %.

TABLE 2 Chemical Requirements of Ferritic and Martensitic Stainless Steels

Grade	Composition, %										
	Carbon, max	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Aluminum	Copper	Nitrogen	Selenium
						Martensitic						
MT 403	0.15	1.00	0.040	0.030	0.50	0.50 max	11.5–13.0	0.60 max				
MT 410	0.15	1.00	0.040	0.030	1.00	0.50 max	11.5–13.5	...	...	...	...	...
MT 414	0.15	1.00	0.040	0.030	1.00	1.25–2.50	11.5–13.5	...	...	...	...	...
MT 416Se	0.15	1.25	0.060	0.060	1.00	0.50 max	12.0–14.0	...	...	...	...	0.12–0.20
MT 431	0.20	1.00	0.040	0.030	1.00	1.25–2.50	15.0–17.0	...	...	...	...	...
MT 440A	0.60 to 0.75	1.00	0.040	0.030	1.00	...	16.0–18.0	0.75 max	...	...	...	...
						Ferritic						
MT 405	0.08	1.00	0.040	0.030	1.00	0.50 max	11.5–14.5	...	0.10–0.30	...	...	...
MT 429	0.12	1.00	0.040	0.030	1.00	0.50 max	14.0–16.0	...	...	...	...	...
MT 430	0.12	1.00	0.040	0.030	1.00	0.50 max	16.0–18.0	...	...	...	...	...
MT 443	0.20	1.00	0.040	0.030	1.00	0.50 max	18.0–23.0	...	...	0.90–1.25	...	...
MT 446–1	0.20	1.50	0.040	0.030	1.00	0.50 max	23.0–30.0	...	...	...	0.25 max	...
MT 446–2[A]	0.12	1.50	0.040	0.030	1.00	0.50 max	23.0–30.0	...	...	...	0.25 max	...
29-4	0.010	0.30	0.025	0.020	0.20	0.15 max	28.0–30.0	3.5–4.2	...	0.15 max	0.020 max	...
29-4-2	0.010	0.30	0.025	0.020	0.20	2.0–2.5	28.0–30.0	3.5–4.2	...	0.15 max	0.020 max[B]	...

[A]MT446-2 is a lower carbon version of MT446-1, that has a lower tensile strength but improved ductility and toughness.

[B]Carbon plus nitrogen = 0.025 max %.

4.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

4.5 The tubes shall be made by a seamless process and by either cold working or hot working as specified. Seamless steel tubing is a tubular product made without a welded seam. It is usually manufactured by hot working steel and then cold finishing the hot-worked tubing to produce the desired shape, dimensions, and properties.

5. Condition

5.1 Round seamless stainless mechanical tubing is generally supplied in the cold-worked and annealed condition (see 5.2 through 5.4). Square, rectangular, or other shapes of tubing are generally supplied annealed prior to final cold shaping. If some other condition is desired, details shall be included in the order.

5.2 The thermal treatment for ferritic and martensitic steels shall be performed by a method and at a temperature selected by the manufacturer unless otherwise specified by the purchaser.

5.3 Unless otherwise specified, all austenitic tubes shall be furnished in the annealed condition. The anneal shall consist of heating the material to a minimum temperature of 1900°F (1040°C) and quenching in water or rapidly cooling by other means. Alternatively, immediately following hot forming while the temperature of the tubes is not less than the specified minimum solution treatment temperature, tubes may be individually quenched in water or rapidly cooled by other means. This anneal shall precede final cold work, when cold-worked tempers are required.

5.4 If any controlled microstructural characteristics are required, these shall be specified so as to be a guide to the most suitable heat treatment.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1 or Table 2. Other grades are available.

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified. When requested in the order or contract, a report of this analysis shall be furnished to the purchaser.

8. Product Analysis

8.1 An analysis of either one billet or one tube shall be made for each heat of steel. Samples for chemical analysis, except spectrochemical analysis, shall be taken in accordance with Method E 59. The chemical composition thus determined shall conform to the requirements specified in Section 6.

8.2 If the original test for product analysis fails, retests of two additional billets 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 producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of this specification shall be rejected.

9. Permissible Variations in Dimensions of Round Tubing

9.1 *Diameter and Wall Thickness (Cold Finished)*—Variations in outside diameter and wall thickness shall not exceed the amounts prescribed in Table 3.

9.2 *Diameter and Wall Thickness (Hot Finished)*—Variations in outside diameter and wall thickness shall not exceed the amounts prescribed in Table 4.

9.3 *Lengths (Cold Finished or Hot Finished)*—Mechanical tubing is commonly furnished in mill lengths 5 ft (1.5 m) and over. When random lengths are ordered, tube lengths may vary by an amount up to 7 ft (2.1 m). Definite cut lengths are furnished, when specified, to the length tolerances shown in Table 3 or Table 4. For tubing ordered in multiple lengths, it is common practice to allow a definite amount over for each multiple for the purchaser's cutting operations. This amount depends on the type of purchaser's cutting and varies with differing wall thickness. The cutting allowance should be specified on the purchase order. When it is not specified, tubing is customarily supplied with the following allowance for each multiple:

Wall Thickness, in. (mm)	Excess Length per Multiple, in. (mm)
Up to ⅛ (3.2)	⅛ (3.2)
Over ⅛ to ½ (3.2 to 12.7)	3⁄16 (4.8)
Over ½ (12.7)	¼ (6.4)

9.4 *Straightness Tolerances (Cold Finished or Hot Finished)*—The deviation from straightness shall not exceed the amounts shown in Table 5 when measured with a 3-ft (0.9-m) straightedge and feeler gage. If determined by the dial

TABLE 3 Permissible Variations in Outside Diameter, Ovality, Wall Thickness, and Cut-Length Variations (Cold-Finished Round Tubing)[A]

Outside Diameter, in.	Outside Diameter, Tolerance,[B] in. Over and Under	Ovality,[B] Double Outside Diameter Tolerance when wall is:	Wall Thickness in %[C,D]		Permissible Variations in Cut Length, in.[E]	
			Over	Under	Over	Under
Under ½	0.005	less than 0.015 in.	15	15	⅛	0
½ to 1½ , excl	0.005	less than 0.065 in.	10	10	⅛	0
1½ to 3½ , excl	0.010	less than 0.095 in.	10	10	3⁄16	0
3½ to 5½ , excl	0.015	less than 0.150 in.	10	10	3⁄16	0
5½ to 8, excl	0.030	less than 0.240 in.	10	10	3⁄16	0
8 to 8⅝ , excl	0.045	less than 0.300 in.	10	10	3⁄16	0
8⅝ to 12¾ , incl	0.062	less than 0.350 in.	10	10	3⁄16	0

[A]Tolerances of tubes produced by the rod or bar mandrel process and which have an inside diameter under ½ in. (12.7 mm) (or an inside diameter under ⅝ in. (15.8 mm) when the wall thickness is more than 20 % of the outside diameter) are as shown in this table, except that wall thickness tolerances are 10 % over and under the specified wall thickness.

[B]For ovality values, the tolerance for average outside diameter at any one cross section does not exceed the outside diameter tolerance value for the applicable outside diameter.

[C]Many tubes with wall thicknesses more than 25 % of outside diameter or with wall thicknesses over 1¼ in., (31.7 mm) or weighing more than 90 lb/ft, are difficult to draw over a mandrel. Therefore, the wall thickness can vary 12½ % over and under that specified. Also see Footnote (*B*).

[D]For those tubes with inside diameter under ½ in. (12.7 mm) (or under ⅝ in. (15.8 mm) when the wall thickness is more than 20 % of the outside diameter) which are not commonly drawn over a mandrel, Footnote (*A*) is not applicable. Therefore, the wall thickness can vary 15 % over and under that specified, and the inside diameter is governed by both the outside diameter and wall thickness tolerances.

[E]These tolerances apply to cut lengths up to and including 24 ft. (7.3 m). For lengths over 24 ft, an additional over tolerance of ⅛ in. (3.1 mm) for each 10 ft (3 m) or fraction thereof shall be permissible, up to a maximum tolerance of ½ in. (12.7 mm).

TABLE 4 Permissible Variations in Outside Diameter, Wall Thickness, and Cut-Length Variations (Hot-Finished Round Tubing)

Specified Size, Outside Diameter, in.	Ratio of Wall Thickness to Outside Diameter	Outside Diameter and Wall Thickness Tolerances										Permissible Variations in Cut Length, in.[A]	
		Outside Diameter, in.		Wall Thickness, %									
				0.109 in. and under		0.109 to 0.172 in., incl		Over 0.172 to 0.203 in., incl		Over 0.203 in.			
		Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 3	all wall thicknesses	0.023	0.023	16.5	16.5	15	15	14	14	12.5	12.5	3⁄16	0
3 to 5½ , excl	all wall thicknesses	0.031	0.031	16.5	16.5	15	15	14	14	12.5	12.5	3⁄16	0
5½ to 8, excl	all wall thicknesses	0.047	0.047	...	...	...	...	14	14	12.5	12.5	3⁄16	0
8 to 10¾ , excl	5 % and over	0.047	0.047	...	...	...	...	...	...	12.5	12.5	3⁄16	0
10¾ to 12¾ , incl	under 5 %	0.063	0.063	...	...	...	...	...	...	12.5	12.5	3⁄16	0

[A]These tolerances apply to cut lengths up to and including 24 ft (7.3 m). For lengths over 24 ft, an additional over tolerance of ⅛ in. (3.1 mm) for each 10 ft (3 m) or faction thereof shall be permissible, up to a maximum tolerance of ½ in. (12.7 mm).

TABLE 5 5 Straightness Tolerances (Cold-/Finished or Hot-/Finished Round Tubing)[A]

Size Limits	Max Curvature in any 3 ft, in.	Max Curvature in Total Lengths, in.	Max Curvature for Lengths under 3 ft
OD 5 in. and smaller. Wall thickness, over 3 % of OD but not over 0.5 in.	0.030	0.030 × [(Number of feet of length)/3]	Ratio of 0.010 in./ft
OD over 5 in. to 8 in., incl. Wall thickness, over 4 % of OD but not over 0.75 in.	0.045	0.045 × [(Number of feet of length)/3]	Ratio of 0.015 in./ft
OD over 8 in. to 12¾ , incl. Wall thickness, over 4 % of OD but not over 1 in.	0.060	0.060 × [(Number of feet of length)/3]	Ratio of 0.020 in./ft

[A]The usual procedure for measuring straightness is by means of a 3-ft (0.9 m) straight edge and feeler gage. If determined by the dial indicator method, the values obtained will be approximately twice those determined by the straightedge feeler gage method.

indicator method, the values obtained will be approximately twice those determined by the straightedge feeler gage method.

10. Permissible Variations in Dimensions of Square and Rectangular Tubing

10.1 Square and rectangular seamless stainless mechanical tubing is supplied as cold worked unless otherwise specified. For this tubing, variations in dimensions from those specified shall not exceed the amounts prescribed in Table 6, Table 7, Table 8, and Table 9.

10.2 The squareness of sides is commonly determined by one of the following methods.

TABLE 6 Permissible Variations in Outside Dimensions for Square and Rectangular Seamless Mechanical Tubing[AB]

Largest Outside Dimension Across Flats, in.	Tolerances, Outside Dimension Seamless Mechanical Tubing Plus and Minus, in.	
	For Wall Thickness, Given, in.	Tolerance for Outside Dimension (Including Convexity or Concavity) Plus and Minus, in.
To ¾ , incl	0.065 and lighter	0.015
To ¾ , incl	over 0.065	0.010
Over ¾ to 1¼ , incl	all thicknesses	0.015
Over 1¼ to 2½ , incl	all thicknesses	0.020
Over 2½ to 3½ , incl	0.065 and lighter	0.030
Over 2½ to 3½ , incl	over 0.065	0.025
Over 3½ to 5½ , incl	all thicknesses	0.030
Over 5½ to 7½ , incl	all thicknesses	1 %

[A]The wall thickness tolerance is plus and minus 10 % of nominal wall thickness.
[B]The straightness tolerance is 0.075 in. 3 ft. using a 3-ft straight edge and feeler gage.

TABLE 7 Permissible Variations in Radii of Corners for Square and Rectangular Seamless Mechanical Tubing

Wall Thickness, in.	Maximum Radii of Corners, in.
Over 0.020 to 0.049, incl	3⁄32
Over 0.049 to 0.065, incl	⅛
Over 0.065 to 0.083, incl	9⁄64
Over 0.083 to 0.095, incl	3⁄16
Over 0.095 to 0.109, incl	13⁄64
Over 0.109 to 0.134, incl	7⁄32
Over 0.134 to 0.156, incl	¼
Over 0.156 to 0.188, incl	9⁄32
Over 0.188 to 0.250, incl	11⁄32
Over 0.250 to 0.313, incl	7⁄16
Over 0.313 to 0.375, incl	½
Over 0.375 to 0.500, incl	11⁄16
Over 0.500 to 0.625, incl	27⁄32

TABLE 8 Twist Tolerances for Square and Rectangular Tubing

Largest Size	Maximum Twist in 3 ft, in.
Under ½	0.050
½ to 1½ , incl	0.075
Over 1½ to 2½ , incl	0.095
Over 2½	0.125

10.2.1 A square, with two adjustable contact points on each arm, is placed on two sides. A fixed feeler gage is then used to measure the maximum distance between the free contact point and the surface of the tubing.

10.2.2 A square, equipped with a direct reading vernier, may be used to determine the angular deviation which, in turn, may be related to distance in inches.

TABLE 9 Length Tolerances for Square and Rectangular Tubing

Length tolerance on exact lengths of tubing (all types)	+3⁄8 , − 0

10.3 The squareness of sides varies in accordance with the following equation:

$$\pm b = c \times 0.006$$

where:
b = tolerance for out-of-square, and
c = length of longest side.

Example: Rectangular tubes 2 by 1 may have sides fail to be 90° to each other by ±0.012 in.

10.4 The twist in square and rectangular tubing may be measured by holding one end of the tubing on a surface plate and noting the height above the surface plate of either corner of the opposite end of the same side. Twist may also be measured by the use of a beveled protractor, equipped with a level, and noting the angular deviation on opposite ends, or at any point throughout the length.

11. Workmanship, Finish, and Appearance

11.1 Finished tubes shall have smooth ends free of burrs. They shall be free of injurious defects and shall have a workmanlike finish. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits and scale pattern, will not be considered as injurious defects, provided the imperfections are removable within the wall tolerance unless a machining allowance has been specified. When a machining allowance has been specified, the imperfections shall be removable within the machining allowances. The removal of surface imperfections is not required.

11.2 Tubes shall be free of scale and suitable for inspection.

12. Machining Allowances of Round Tubing

12.1 Clean-up or machining allowances for stainless steel round mechanical tubing are shown in Table 10. For the method of calculating the tube size required to clean up in machining to a particular finished part, see Appendix X1.

13. Rejection

13.1 Tubing that fails to meet the requirements of this specification shall be set aside and the manufacturer notified.

14. Coating

14.1 Stainless tubing is commonly shipped without protective coating. If special protection is needed, details shall be shown on the order.

TABLE 10 Cleanup or Machining Allowances for Round Tubing[A]

For Machined Parts Size, Outside Diameter, in.	Machining Allowances on Diameter, in.	
	Outside Diameter	Inside Diameter
Less than 3⁄32	0.008	0.008
3⁄32 to 3⁄16 , excl	0.012	0.012
3⁄16 to 1⁄2 , excl	0.015	0.015
1⁄2 to 11⁄2 , excl	0.020	0.020
11⁄2 to 3, excl	0.040	0.040
3 to 51⁄2 , excl	0.060	0.060
51⁄2 to 8,[B] excl	0.080	0.080

[A]The allowances in this table are nominal allowances which have been satisfactorily used for many applications but are not necessarily adequate for all tubular products and methods of machining. For example, when magnetic particle inspection or aircraft quality requirements are involved, it is customary to use greater allowances than those shown in the foregoing table.

[B]For machining allowances for sizes 8 in. and over the producer should be consulted.

15. Product and Package Marking

15.1 *Civilian Procurement*—Each box, bundle, lift, or piece shall be identified by a tag or stencil with the manufacturer's name or brand, specified size, purchaser's order number, grade, and this specification number.

15.2 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the Government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for Military agencies and in accordance with Fed. Std. No. 123 for civil agencies.

16. Packaging

16.1 *Civilian Procurement*—On tubing 0.065 in. (1.65 mm) wall and under, the manufacturer will, at his option, box, crate, carton, package in secure lifts, or bundle to ensure safe delivery. Tubing over 0.065 in. (1.65 mm) wall will normally be shipped loose, bundled, or in secured lifts. Special packaging requiring extra operations other than those normally used by the manufacturer must be specified on the order.

16.2 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the Government when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

17. Keywords

17.1 austenitic stainless steel; mechanical tubing; seamless steel tube; stainless steel tube; steel tube

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order and the necessary tests shall be made at the mill. Mechanical tests shall be performed in accordance with Test Methods and Definitions A 370.

S1. Hardness Test

S1.1 The tubes shall conform to the hardness limits specified in Table S1.1, unless cold worked tempers or special thermal treatments are ordered, in which case the manufacturer should be consulted for expected hardness values. S1.2 When specified, the hardness test shall be performed on a specimen from one tube from each lot of 100 tubes or fraction thereof from each heat of steel.

S2. Tension Test

S2.1 Unless cold-worked tempers or special thermal treatments are ordered, the tubes shall conform to the tensile requirements shown in Table S2.1. When cold-worked tempers or special thermal treatments are ordered, the tube manufacturer should be consulted.

S2.2 When the tension test is specified, one test shall be performed on a specimen from one tube taken from each lot of 100 tubes or fraction thereof from each heat of steel.

S2.3 The yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen or to a total extension of 0.5 % of the gage length under load shall be determined.

S3. Nondestructive Tests

S3.1 Various types of nondestructive ultrasonic or electromagnetic tests are available. When any such test is required, the test to be used and the inspection limits required shall be specified. Generally, for ultrasonic test, the most restrictive limit which may be specified is 3 % of the wall thickness or 0.004 in. (0.10 mm) (whichever is greater). For a description and inspection table of another type of non-destructive electric test, see the section on Nondestructive Electric Test in Specification A 1016/A 1016M.

TABLE S1.1 Hardness Requirements for Round Tubing in Annealed Condition[A]

Grade	Brinell Hardness Number, max	Rockwell Hardness Number, B Scale, max
All austenitic	192	90
MT 403	207	95
MT 405	207	95
MT 410	207	95
MT 414	235	99
MT 416 Se	230	97
MT 429/MT 430	190	90
MT 431	260	. . .
MT 440 A	215	95
MT 443	207	95
MT 446	207	95
29-4	207	95
29-4-2	207	95

[A]Not applicable when cold-worked tempers or special thermal treatment is ordered.

TABLE S2.1 Tensile Requirements for Round Tubing in Annealed Condition[A]

Grade	Tensile Strength, min, ksi (MPa)	Yield Strength min, ksi (MPa)	Elongation[B] in 2 in., or 50 mm min., %
All austenitic steels[C]	75 (517)	30 (207)	35
MT 403	60 (414)	30 (207)	20
MT 405	60 (414)	30 (207)	20
MT 410	60 (414)	30 (207)	20
MT 414	100 (689)	65 (448)	15
MT 416 Se	60 (414)	35 (241)	20
MT 429/MT 430	60 (414)	35 (241)	20
MT 431	105 (724)	90 (621)	20
MT 440 A	95 (655)	55 (379)	15
MT 443	70 (483)	40 (276)	20
MT 446–1	70 (483)	40 (276)	18
MT 446–2	65 (448)	40 (276)	20
29-4	70 (483)	55 (379)	20
29-4-2	70 (483)	55 (379)	20

[A]Not applicable to tubes under a ⅛ in. (3.1 mm) outside diameter or less than 0.015 in. (0.38 mm) in wall thickness, or both. The tensile properties of such small diameter or thin wall tubes are a matter of agreement between manufacturer and purchaser. For tubing having an outside diameter of ⅜ in. or under, the gage length shall be four times the outside diameter in order to obtain elongation values comparable to the larger sizes (Test Methods and Definitions A 370).

[B]For longitudinal strip tests, the width of the gage section shall be 1 in. (25.4 mm). A deduction of 1.0 percentage points for ferritic and martenistic grades shall be permitted from the basic minimum elongation for each 1⁄32 in. (0.8 mm) decrease in wall thickness under 5⁄16 in. (7.9 mm). The calculated elongation requirement shall be rounded to the nearest whole number.

[C]When grades TP304L, and TP316L are required to pass special corrosion tests, these minimum values for tensile strength and yield strength may not be met.

S4. Hardenability

S4.1 Any requirement for special hardenability tests and test limits for martensitic stainless grades shall be detailed on the order. Hardenability requirements are not applicable to austenitic or ferritic grades.

S5. Surface Finish

S5.1 Any special pickling, shortblasting, or polishing requirements shall be detailed in the order.

S6. Certification for Government Orders

S6.1 A producer's or supplier's certification shall be furnished to the Government that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. This certificate shall include a report of heat analysis (product analysis when requested in the purchase order), and when specified in the purchase order or contract, a report of test results shall be furnished.

S7. Rejection Provisions for Government Orders

S7.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the tube may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

S7.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such materials shall be a matter for agreement.

APPENDIX

(Nonmandatory Information)

X1. MACHINING ALLOWANCES FOR CARBON, ALLOY AND STAINLESS STEEL SEAMLESS MECHANICAL TUBING

X1.1 Seamless mechanical tubing is produced either hot finished or cold worked. Hot finished tubes are specified to outside diameter and wall thickness. Cold-worked tubing is specified to two of the three dimensions: outside diameter, inside diameter, and wall thickness.

X1.2 There are two basic methods employed in machining such tubing: (*1*) by machining true to the outside diameter of the tube and (*2*) by machining true to the inside diameter of the tube.

X1.3 For the purpose of determining tube size dimensions with sufficient allowances for machining, the following four steps are customarily used.

X1.4 Step 1—Step 1 is used to determine the maximum tube outside diameter.

X1.4.1 *Machined Outside Diameter*—Purchaser's maximum blueprint (finish-machine) size including plus machine tolerance.

X1.4.2 *Cleanup Allowance*—Sufficient allowance should be made to remove surface imperfections.

X1.4.3 *Decarburization*— Decarburization is not important in most stainless grades but is an important factor on the higher carbon grades or steel including Type 440A. Decarburization limits are shown in various specifications. For example, the decarburization limits for aircraft steels are shown in AMS and appropriate government specifications. Decarburization is generally expressed as depth and, therefore must be doubled to provide for removal from the surface.

X1.4.4 *Camber*—When the machined dimension extends more than 3 in. (76.2 mm) from the chuck or other holding mechanism, the possibility that the tube will be out-of-straight must be taken into consideration. An allowance is made equal to four times the straightness tolerance shown in Table 5, for the machined length when chucked at only one end and equal to twice the straightness tolerance if supported at both ends.

X1.4.5 *Outside Diameter Tolerance*—If machined true to the outside diameter, add the complete spread of tolerance (for example, for specified outside diameter of 3 to 5½ in. (76.2 to 139.7 mm), exclusive, plus and minus 0.031 in. or 0.062 in.). If machined true to the inside diameter, outside diameter tolerances are not used in this step. Cold-worked tolerances are shown in Table 3. Hot-finished tolerances are shown in Table 4. The calculated maximum outside diameter is obtained by adding X1.4.1 through X1.4.5.

X1.5 Step 2—Step 2 is used to determine the minimum inside diameter.

X1.5.1 *Machined Inside Diameter*

Purchaser's minimum blueprint (finished-machine) size including machining tolerance.

X1.5.2 *Cleanup Allowance*—Sufficient allowance should be made to remove surface imperfections.

X1.5.3 *Decarburization*— Decarburization is an important factor on the higher carbon grades of steel including Type 440A. Decarburization limits are shown in various specifications. For example, the decarburization limits for aircraft are shown in AMS and appropriate government specifications. Decarburization is generally expressed as depth and therefore must be doubled to provide for removal from the surface.

X1.5.4 *Camber*—Refer to X1.4.4.

X1.5.5 *Inside Diameter Tolerances*—If machined true to the outside diameter, inside diameter tolerances are not used in this step. If machined true to the inside diameter, subtract the complete spread of tolerance (plus and minus). Cold-worked tolerances are shown in Table 5. Hot-finished tolerances (use outside diameter tolerances for inside diameter for calculating purposes) are shown in Table 4. The calculated minimum is obtained by subtracting the sum of X1.5.2 through X1.5.5 from X1.5.1.

X1.6 Step 3—Step 3 is used to determine the average wall thickness.

X1.6.1 One half the difference between the maximum outside diameter and the minimum inside diameter is considered to be the calculated minimum wall. From the calculated minimum wall, the average is obtained by dividing by 0.90 for cold-worked tubing or 0.875 for hot-finished tubing. This represents the wall tolerance of plus and minus 10 % for cold-worked tubing and plus and minus 12½ % for hot-finished tubing. The wall tolerances may be modified in special cases as covered by applicable tables.

X1.7 Step 4—Step 4 is used to determine cold-worked or hot-finished tube size when machined true to the outside diameter or machined true to the inside diameter.

X1.7.1 *Cold Worked Machined True to Outside Diameter*—Size obtained in Step 1 minus the over tolerance (shown in “Over” column in Table 3) gives the outside diameter to be specified. The wall thickness to be specified is that determined in Step 3.

X1.7.2 *Cold Worked Machined True to Inside Diameter*—Size obtained in Step 2 plus twice the calculated wall obtained in Step 3 gives the minimum outside diameter. To find the outside diameter to be specified, add the under part of the tolerance shown in the under outside diameter column in Table 3. The average wall thickness to be specified is that determined in Step 3. If necessary to specify to inside diameter and wall, the under tolerance for inside diameter (shown in Table 3) is added to the inside diameter obtained in Step 2.

X1.7.3 *Hot Finished Machined True to Outside Diameter*—From the size obtained in Step 1, subtract one-half the total tolerance (shown in Table 4) to find the outside diameter to be specified. The average wall thickness to be specified is that determined in Step 3.

X1.7.4 *Hot Finished Machined True to Inside Diameter*—The average outside diameter to be specified is obtained by adding the under part of the tolerance (shown in the under column of Table 4) to the minimum outside diameter, calculated by adding twice the average wall (from Step 3) to the minimum inside diameter (from Step 2).

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 511 – 96, that may impact the use of this specification. (Approved March 1, 2004)

(*1*) Replaced A 450/A 450M with A 1016/A 1016M in 2.1 and S3.1.

Designation: A 501 – 07

Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing[1]

This standard is issued under the fixed designation A 501; 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*

1.1 This specification covers black and hot-dipped galvanized hot-formed welded and seamless carbon steel square, round, rectangular, or special shape structural tubing for welded, riveted, or bolted construction of bridges and buildings, and for general structural purposes.

1.2 Square and rectangular tubing is furnished in sizes 1 to 32 in. (25.4 to 813 mm) across flat sides with wall thicknesses 0.095 to 3.00 in. (2.41 to 76 mm), dependent upon size; round tubing is furnished in NPS ½ to NPS 24 (see Note 1) inclusive, with nominal (average) wall thicknesses 0.109 to 1.000 in. (2.77 to 25.40 mm), dependent upon size. Special shape tubing and tubing with other dimensions is permitted to be furnished, provided that such tubing complies with all other requirements of this specification.

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 specification covers the following grades:

1.3.1 Grade A — 36 000 psi (250 MPa) min yield strength.

1.3.2 Grade B — 50 000 psi (345 MPa) min yield strength.

1.4 An optional supplementary requirement is provided for Grade B and, when desired, shall be so stated on the order.

1.5 The following precautionary statement pertains only to the test method portion of this specification: *This standard does not purport to address all the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.6 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.7 The text of this specification contains notes and footnotes that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 53/A 53M Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

2.2 *AIAG Standard:*[3]

B-1 Bar Code Symbology Standard

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A 941.

4. Ordering Information

4.1 Orders for material under this specification shall contain information concerning as many of the following items as are required to describe the desired material adequately:

4.1.1 Quantity (feet or number of lengths),

4.1.2 Name of material (hot-formed tubing),

4.1.3 Grade (A or B)

4.1.4 Method of manufacture (seamless or welded) (see Section 6),

4.1.5 Finish (black or galvanized),

4.1.6 Size (outside diameter and calculated nominal wall thickness for round tubing and the outside dimensions and calculated nominal wall thickness for square and rectangular tubing (Section 11)),

[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 A01.09 on Carbon Steel Tubular Products.

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[2] 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.

[3] Available from Automotive Industry Action Group (AIAG), 26200 Lahser Rd., Suite 200, Southfield, MI 48033, http://www.aiag.org.

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

4.1.7 Length (random, multiple, or specific; see 12.3),
4.1.8 End condition (see 17.3),
4.1.9 Burr removal (see 17.3),
4.1.10 Certification (see Section 19),
4.1.11 ASTM specification designation and year of issue,
4.1.12 End use,
4.1.13 Special requirements, and
4.1.14 Bar coding (see 20.3).

5. Process

5.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

5.2 When steels of different grades are sequentially strand cast, the steel producer shall identify the resultant transition material and remove it using an established procedure that positively separates the grades.

6. Manufacture

6.1 The tubing shall be made by one of the following processes: seamless; furnace-butt welding (continuous welding); electric-resistance welding or submerged arc welding followed by reheating throughout the cross section and hot forming by a reducing or shaping process, or both.

7. Heat Analysis

7.1 Each heat analysis shall conform to the requirements specified in Table 1 for heat analysis.

8. Product Analysis

8.1 The tubing shall be capable of conforming to the requirements specified in Table 1 for product analysis.

8.2 If product analyses are made, they shall be made using test specimens taken from two lengths of tubing from each lot of 500 lengths, or fraction thereof, or two pieces of flat-rolled stock from each lot of a corresponding quantity of flat-rolled stock. Methods and practices relating to chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751. Such product analyses shall conform to the requirements specified in Table 1 for product analysis.

8.3 If both product analyses representing a lot fail to conform to the specified requirements, the lot shall be rejected.

8.4 If only one product analysis representing a lot fails to conform to the specified requirements, product analyses shall be made using two additional test specimens taken from the lot. Both additional product analyses shall conform to the specified requirements or the lot shall be rejected.

9. Tensile Requirements

9.1 The material, as represented by the test specimen, shall conform to the requirements as to tensile properties prescribed in Table 2.

9.2 The yield strength corresponding to a permanent offset of 0.2 % of the gauge length of the specimen or to a total extension of 0.5 % of the gauge length under load shall be determined.

10. Charpy V-Notch Impact Test

10.1 The Charpy V-notch impact test applies to Grade B only and wall thickness greater than 0.312 in. (8 mm).

10.1.1 Charpy V-notch tests shall be made in accordance with Test Methods and Definitions A 370

10.1.2 One Charpy V-notch impact test shall be made from a length of tubing representing each lot.

10.1.3 The test results of full-size longitudinal specimens shall meet an average value of 20 ft-lb at 0 °F (-18 °C).

11. Dimensions

11.1 *Square Structural Tubing*—The outside dimensions (across the flats), the weight per foot, and the calculated nominal wall thickness of common sizes of square structural tubing included in this specification are listed in Table 3.

11.2 *Rectangular Structural Tubing*—The outside dimensions (across the flats), the weight per foot, and the calculated nominal wall thickness of common sizes of rectangular structural tubing included in this specification are listed in Table 4.

11.3 *Round Structural Tubing*—The NPS and outside diameter dimensions, the weight per foot, and the calculated nominal wall thickness of common sizes of round structural tubing included in this specification are listed in Table 5.

11.4 *Special Shape Structural Tubing*—The dimensions and tolerances of special shape structural tubing are available by inquiry and negotiation with the manufacturer.

11.5 *Other Sizes*—The dimensional tolerances for hot-formed welded and seamless structural tubing manufactured in accordance with the requirements of this specification, but with ordered dimensions other than those listed in Table 3, Table 4, and Table 5, shall be consistent with those given in this specification for similar sizes and type of product.

12. Permissible Variations in Dimensions of Square, Round, Rectangular, and Special Shape Structural Tubing

12.1 *Outside Dimensions*:

TABLE 1 Chemical Requirements[A]

	Composition, %			
	Grade A		Grade B	
Element	Heat analysis	Product analysis	Heat analysis	Product analysis
Carbon, max	0.26	0.30	0.22[B]	0.26
Manganese, max	...	...	1.40[B]	1.45
Phosphorus, max	0.035	0.045	0.030	0.040
Sulfur, max	0.035	0.045	0.020	0.030
Copper, when copper steel is specified, min	0.20	0.18	0.20	0.18

[A] Where an ellipsis (...) appears in this table, there is no requirement.

[B] For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 % by heat analysis and 1.60 % by product analysis.

TABLE 2 Tensile Requirements

	Grade A	Grade B
Tensile strength, min, psi (MPa)	58 000 (400)	70 000 (483)
Yield strength, min, psi (MPa)	36 000 (250)	50 000 (345)
Elongation in 2 in. (50.8 mm), min, %	23	23

12.1.1 *Round Structural Tubing*—For round hot-formed structural tubing NPS 2 and over, the outside diameter shall not vary more than ±1 % from the specified outside diameter. For NPS 1½ and under, the outside diameter shall not vary more than 1⁄64 in. (0.40 mm) over or more than 1⁄32 in. (0.79 mm) under the specified outside diameter.

12.1.2 *Square, Rectangular, and Special Shape Structural Tubing*—The outside dimensions, measured across the flats at positions at least 2 in. (50.8 mm) from the ends of the tubing, shall not vary from the specified outside dimensions by more than the applicable amount given in Table 6, which includes an allowance for convexity or concavity.

12.2 *Weight*—The weight of the structural tubing shall be not more than 3.5 % under its theoretical weight, as calculated using its length and the applicable weight per unit length given in Table 3, Table 4, or Table 5.

12.3 *Length*—Structural tubing is commonly produced in random lengths of 16 to 22 ft. (4.9 to 6.7 m) or 32 to 44 ft. (9.8 to 13.4 m), in multiple lengths, and in specific lengths. When specific lengths are ordered, the permissible variations in length shall be as given in Table 7.

12.4 *Straightness*—The permissible variation for straightness of structural tubing shall be ⅛ in. times the number of feet (10.4 mm times the number of metres) of total length divided by five.

12.5 *Squareness of Sides*—For perpendicular and rectangular tubing, adjacent sides shall be square (90°), with a permissible variation of ±2°.

12.6 *Radius of Corners*—For square and rectangular structural tubing, the radius of each outside corner of the section shall not exceed three times the calculated nominal wall thickness.

12.7 *Twist*—For square, rectangular, and special shape structural tubing, the permissible variations in twist shall be as given in Table 8. Twist shall be determined by holding one end of the tubing down on a flat surface plate, measuring the height that each corner on the bottom side of the tubing extends above the surface plate near the opposite end of the tubing, and calculating the twist (the difference in the measured heights of such corners), except that for heavier sections it shall be permissible to use a suitable measuring device to determine twist. Twist measurements shall not be taken within 2 in. (50.8 mm) of the ends of the tubing.

13. Number of Tests

13.1 One tension test as specified in 15.2 shall be made from a length of tubing representing each lot.

13.2 The term "lot" shall apply to all tubes of the same specified size that are produced from the same heat of steel.

14. Retests

14.1 If the results of the mechanical tests representing any lot fail to conform to the applicable requirements specified in Sections 9 and 10, the lot shall be rejected or retested using additional tubing of double the original number from the lot. The lot shall be acceptable if the results of all such retests representing the lot conform to the specified requirements.

14.2 If one or both of the retests specified in 14.1 fail to conform to the applicable requirements specified in Sections 9 and 10, the lot shall be rejected or, subsequent to the manufacturer heat treating, reworking, or otherwise eliminating the condition responsible for the failure, the lot shall be treated as a new lot and tested accordingly.

15. Test Method

15.1 Tension test specimens shall conform to the applicable requirements of Test Methods and Definitions A 370, Annex A2.

15.2 Tension test specimens shall be full-size longitudinal test specimens or longitudinal strip test specimens. For welded tubing, any longitudinal strip test specimens shall be taken from a location at least 90° from the weld and shall be prepared without flattening in the gauge length. Longitudinal strip test specimens shall have all burrs removed. Tension test specimens shall not contain surface imperfections that would interfere with proper determination of the tensile properties.

15.3 The yield strength corresponding to an offset of 0.2 % of the gauge length or to a total extension under load of 0.5 % of the gauge length shall be determined.

16. Galvanized Coatings

16.1 For structural tubing required to be hot-dipped galvanized, such coating shall comply with the requirements contained in Specification A 53/A 53M, except that the manufacturer shall additionally have the option of determining the coating weight using only the values obtained for the coating on the outside surface of the tubing.

17. Inspection

17.1 All tubing shall be inspected at the place of manufacture to ensure conformance with the requirements of this specification.

17.2 The structural tubing shall be free of defects and shall have a commercially smooth finish.

17.2.1 Surface imperfections shall be classed as defects when one or more of the following conditions exist:

17.2.1.1 The depth of the imperfections exceeds 15 % of the calculated nominal wall thickness.

17.2.1.2 The imperfections materially affect the appearance of the structural tubing.

17.2.1.3 At any location, the length of the imperfections, measured in the transverse direction, in combination with their depth materially reduce the total cross sectional area of the structural tubing.

TABLE 3 Dimensions of Common Sizes of Square Structural Tubing

Size Given in Outside Dimensions Across Flat Sides, in. (mm)	Weight per Unit Length, lb/ft (kg/m)	Calculated Nominal Wall Thickness, in. (mm)
1 by 1	1.09 (1.62)	0.095 (2.41)
(25.4 by 25.4)	1.41 (2.10)	0.133 (3.38)
2 by 2	2.69 (4.00)	0.110 (2.79)
(50.8 by 50.8)	3.04 (4.52)	0.125 (3.18)
	3.65 (5.44)	0.154 (3.91)
	4.31 (6.41)	0.188 (4.78)
2½ by 2½	4.32 (6.43)	0.141 (3.58)
(63.5 by 63.5)	5.59 (8.32)	0.188 (4.78)
	7.10 (10.56)	0.250 (6.35)
3 by 3	5.78 (8.60)	0.156 (3.96)
(76.2 by 76.2)	6.86 (10.21)	0.188 (4.78)
	8.80 (13.09)	0.250 (6.35)
3½ by 3½	6.88 (10.24)	0.156 (3.96)
(88.9 by 88.9)	8.14 (12.11)	0.188 (4.78)
	10.50 (15.62)	0.250 (6.35)
	12.69 (18.88)	0.312 (7.92)
4 by 4	9.31 (13.85)	0.188 (4.78)
(101.6 by 101.6)	12.02 (17.89)	0.250 (6.35)
	14.52 (21.61)	0.312 (7.92)
	16.84 (25.06)	0.375 (9.52)
	20.88 (31.07)	0.500 (12.70)
5 by 5	11.86 (17.65)	0.188 (4.78)
(127.0 by 127.0)	15.42 (22.94)	0.250 (6.35)
	18.77 (27.93)	0.312 (7.92)
	21.94 (32.65)	0.375 (9.52)
	27.68 (41.19)	0.500 (12.70)
6 by 6	14.41 (21.44)	0.188 (4.78)
(152.4 by 152.4)	18.82 (28.00)	0.250 (6.35)
	23.02 (34.25)	0.312 (7.92)
	27.04 (40.28)	0.375 (9.52)
	34.48 (51.31)	0.500 (12.70)
7 by 7	16.85 (25.07)	0.188 (4.78)
(177.8 by 177.8)	22.04 (32.80)	0.250 (6.35)
	26.99 (39.16)	0.312 (7.92)
	31.73 (47.21)	0.375 (9.52)
	40.55 (60.34)	0.500 (12.70)
8 by 8	25.44 (37.85)	0.250 (6.35)
(203.2 by 203.2)	31.24 (46.49)	0.312 (7.92)
	36.83 (54.80)	0.375 (9.52)
	38.33 (57.03)	0.38 (9.65)
	47.35 (70.46)	0.500 (12.70)
	49.16 (73.15)	0.50 (12.70)
	56.98 (84.79)	0.625 (15.88)
	60.20 (89.57)	0.63 (16.00)
	65.73 (97.81)	0.750 (19.05)
10 by 10	32.23 (47.96)	0.250 (6.35)
(254.0 by 254.0)	39.74 (59.13)	0.312 (7.92)
	47.03 (69.98)	0.375 (9.52)
	48.68 (72.43)	0.38 (9.65)
	60.95 (90.69)	0.500 (12.70)
	62.78 (93.41)	0.50 (12.70)
	73.98 (110.08)	0.625 (15.88)
	77.35 (115.10)	0.63 (16.00)
	86.13 (128.16)	0.750 (19.05)
	90.19 (134.19)	0.75 (19.05)
	107.79 (160.39)	1.000 (25.40)
12 by 12	76.39 (113.66)	0.50 (12.70)
(304.8 by 304.8)	94.51 (140.62)	0.63 (16.00)
	110.61 (164.58)	0.75 (19.05)
14 by 14	90.01 (133.92)	0.50 (12.70)
(355.6 by 355.6)	111.66 (166.14)	0.63 (16.00)
	131.04 (194.97)	0.75 (19.05)
	140.49 (209.03)	0.81 (20.57)
	145.40 (216.35)	0.87 (22.00)
	162.18 (241.31)	0.98 (25.00)
16 by 16	103.62 (154.18)	0.50 (12.70)
(406.4 by 406.4)	128.81 (191.66)	0.63 (16.00)
	162.52 (241.81)	0.81 (20.57)
	168.99 (251.44)	0.87 (22.00)
	188.98 (281.19)	0.98 (25.00)
	208.24 (309.84)	1.10 (28.00)
18 by 18	267.09 (397.40)	1.26 (32.00)
(457.2 by 457.2)	294.62 (438.36)	1.42 (36.00)
	320.84 (477.38)	1.57 (40.00)
20 by 20	130.85 (194.70)	0.50 (12.70)
(508.0 by 508.0)	163.12 (242.70)	0.63 (16.00)
	192.31 (286.13)	0.75 (19.05)
	206.66 (307.49)	0.81 (20.57)
	214.68 (319.42)	0.87 (22.00)
	240.67 (358.10)	0.98 (25.00)
	265.88 (395.60)	1.10 (28.00)
	298.26 (443.78)	1.26 (32.00)
	329.25 (489.88)	1.42 (36.00)
	358.83 (533.90)	1.57 (40.00)
	393.84 (585.99)	1.77 (45.00)
	426.66 (634.83)	1.97 (50.00)
22 by 22	177.48 (264.08)	0.63 (16.00)
(558.8 by 558.8)	208.27 (309.88)	0.75 (19.00)
	238.27 (354.51)	0.87 (22.00)
	267.48 (397.98)	0.98 (25.00)
	295.90 (440.26)	1.10 (28.00)
	332.57 (494.83)	1.26 (32.00)
	367.84 (547.31)	1.42 (36.00)
	401.71 (597.70)	1.57 (40.00)
	442.08 (657.77)	1.77 (45.00)
	480.27 (714.58)	1.97 (50.00)
	516.26 (768.14)	2.17 (55.00)
24 by 24	194.64 (289.60)	0.63 (16.00)
(609.6 by 609.6)	228.64 (340.19)	0.75 (19.00)
	261.85 (389.61)	0.87 (22.00)
	294.28 (437.85)	0.98 (25.00)
	325.92 (484.93)	1.10 (28.00)
	366.87 (545.87)	1.26 (32.00)
	406.43 (604.73)	1.42 (36.00)
	444.59 (661.51)	1.57 (40.00)
	490.32 (729.55)	1.77 (45.00)
	533.87 (794.34)	1.97 (50.00)
	575.22 (855.87)	2.17 (55.00)
	614.39 (914.15)	2.36 (60.00)
26 by 26	211.79 (315.12)	0.63 (16.00)
(660.4 by 660.4)	249.01 (370.50)	0.75 (19.00)
	285.44 (424.70)	0.87 (22.00)
	321.08 (477.73)	0.98 (25.00)
	355.93 (529.59)	1.10 (28.00)
	401.18 (596.92)	1.26 (32.00)
	445.03 (662.16)	1.42 (36.00)
	487.48 (725.31)	1.57 (40.00)
	538.57 (801.33)	1.77 (45.00)
	587.47 (874.10)	1.97 (50.00)
	634.19 (943.61)	2.17 (55.00)
	678.72 (1009.86)	2.36 (60.00)
28 by 28	228.94 (340.64)	0.63 (16.00)
(711.2 by 711.2)	269.38 (400.80)	0.75 (19.00)

TABLE 3 *Continued*

Size Given in Outside Dimensions Across Flat Sides, in. (mm)	Weight per Unit Length, lb/ft (kg/m)	Calculated Nominal Wall Thickness, in. (mm)
	309.02 (459.79)	0.87 (22.00)
	347.88 (517.61)	0.98 (25.00)
	385.95 (574.25)	1.10 (28.00)
	435.49 (647.96)	1.26 (32.00)
	483.62 (719.58)	1.42 (36.00)
	530.36 (789.12)	1.57 (40.00)
	586.81 (873.11)	1.77 (45.00)
	641.07 (953.85)	1.97 (50.00)
	693.15 (1031.34)	2.17 (55.00)
	743.04 (1105.57)	2.36 (60.00)
30 by 30 762.0 by 762.0)	246.10 (366.17)	0.63 (16.00)
	289.75 (431.11)	0.75 (19.00)
	332.61 (494.88)	0.87 (22.00)
	374.68 (557.49)	0.98 (25.00)
	415.97 (618.92)	1.10 (28.00)
	469.79 (699.00)	1.26 (32.00)
	522.22 (777.00)	1.42 (36.00)
	573.24 (852.92)	1.57 (40.00)
	635.05 (944.89)	1.77 (45.00)
	694.68 (1033.61)	1.97 (50.00)
	752.12 (1119.07)	2.17 (55.00)
	807.36 (1201.28)	2.36 (60.00)

17.2.2 It shall be permissible for defects having a depth not in excess of 33⅓ % of the calculated nominal wall thickness to be repaired by welding, subject to the following conditions:

17.2.2.1 The defect shall be completely removed by chipping or grinding to sound metal,

17.2.2.2 The repair weld shall be made using a low-hydrogen welding process, and

17.2.2.3 The projecting weld metal shall be removed to produce a workmanlike finish.

17.3 Unless otherwise specified in the purchase order, structural tubing shall be furnished with square cut ends. The burr shall be held to a minimum. When so specified in the purchase order, the burr shall be removed on the outside diameter, inside diameter, or both.

18. Rejection

18.1 It shall be permissible for the purchaser to inspect tubing received from the manufacturer and reject any tubing that does not meet the requirements of this specification, based upon the inspection and test methods outlined herein. The purchaser shall notify the manufacturer of any tubing that has been rejected, and the disposition of such tubing shall be subject to agreement between the manufacturer and the purchaser.

18.2 It shall be permissible for the purchaser to set aside any tubing that is found in fabrication or installation within the scope of this specification to be unsuitable for the intended end use, based on the requirements of this specification. The purchaser shall notify the manufacturer of any tubing that has been set aside. Such tubing shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation conditions, or both, involved. The disposition of such tubing shall be subject to agreement between the manufacturer and the purchaser.

TABLE 4 Dimensions of Common Sizes of Rectangular Structural Tubing

Size Given in Outside Dimensions Across Flat Sides, in. (mm)	Weight per Unit Length, lb/ft (kg/m)	Calculated Nominal Wall Thickness, in. (mm)
3 by 2 (76.2 by 50.8)	4.32 (6.43)	0.141 (3.58)
	5.59 (8.32)	0.188 (4.78)
	7.10 (10.56)	0.250 (6.35)
4 by 2 (101.6 by 50.8)	5.78 (8.60)	0.156 (3.96)
	6.86 (10.21)	0.188 (4.78)
	8.80 (13.09)	0.250 (6.35)
4 by 3 (101.6 by 76.2)	6.88 (10.24)	0.156 (3.96)
	8.14 (12.11)	0.188 (4.78)
	10.50 (15.62)	0.250 (6.35)
	12.69 (18.88)	0.312 (7.92)
5 by 3 (127.0 by 76.2)	9.31 (13.85)	0.188 (4.78)
	12.02 (17.89)	0.250 (6.35)
	14.52 (21.61)	0.312 (7.92)
	16.84 (25.06)	0.375 (9.52)
6 by 3 (152.4 by 76.2)	10.58 (15.74)	0.188 (4.78)
	13.72 (20.42)	0.250 (6.35)
	16.65 (24.78)	0.312 (7.92)
	19.39 (28.85)	0.375 (9.52)
6 by 4 (152.4 by 101.6)	11.86 (17.65)	0.188 (4.78)
	15.42 (22.94)	0.250 (6.35)
	18.77 (27.93)	0.312 (7.92)
	21.94 (32.65)	0.375 (9.52)
	27.68 (41.19)	0.500 (12.70)
7 by 5 (177.8 by 127.0)	14.41 (21.44)	0.188 (4.78)
	18.82 (28.00)	0.250 (6.35)
	23.02 (34.25)	0.312 (7.92)
	27.04 (40.28)	0.375 (9.52)
	34.48 (51.31)	0.500 (12.70)
8 by 4 (203.2 by 101.6)	14.41 (21.44)	0.188 (4.78)
	18.82 (28.00)	0.250 (6.35)
	23.02 (34.25)	0.312 (7.92)
	27.04 (40.28)	0.375 (9.52)
	34.48 (51.31)	0.500 (12.70)
8 by 6 (203.2 by 152.4)	16.85 (25.07)	0.188 (4.78)
	22.04 (32.80)	0.250 (6.35)
	26.99 (39.16)	0.312 (7.92)
	31.73 (47.21)	0.375 (9.52)
	33.20 (49.39)	0.38 (9.65)
	40.55 (60.34)	0.500 (12.70)
	42.41 (60.34)	0.500 (12.70)
10 by 4 (254.0 by 101.6)	42.35 (63.02)	0.50 (12.70)
	51.62 (76.81)	0.63 (16.00)
10 by 6 (254.0 by 152.4)	25.44 (37.85)	0.250 (6.35)
	31.24 (46.49)	0.312 (7.92)
	36.83 (54.80)	0.375 (9.52)
	38.33 (57.03)	0.38 (9.65)
	47.35 (70.46)	0.500 (12.70)
	49.16 (73.15)	0.50 (12.70)
	60.20 (89.57)	0.63 (16.00)
12 by 8 (304.8 by 203.2)	62.78 (93.41)	0.50 (12.70)
	77.35 (115.10)	0.63 (16.00)
16 by 8 (406.4 by 203.2)	76.39 (113.66)	0.50 (12.70)
	94.51 (140.62)	0.63 (16.00)
18 by 10 (457.2 by 254.0)	90.01 (133.92)	0.50 (12.70)
	111.66 (166.14)	0.63 (16.00)
20 by 12 (508.0 by 304.8)	103.62 (154.18)	0.50 (12.70)
	128.81 (191.66)	0.63 (16.00)

TABLE 4 *Continued*

Size Given in Outside Dimensions Across Flat Sides, in. (mm)	Weight per Unit Length, lb/ft (kg/m)	Calculated Nominal Wall Thickness, in. (mm)
22 by 14	107.66 (160.19)	0.47 (12.00)
(550.0 by 350.0)	140.75 (209.42)	0.63 (16.00)
	164.64 (244.97)	0.75 (19.00)
	187.75 (279.36)	0.87 (22.00)
	210.07 (312.57)	0.98 (25.00)
	231.61 (344.61)	1.10 (28.00)
24 by 16	120.32 (179.03)	0.47 (12.00)
(600.0 by 400.0)	157.63 (234.54)	0.63 (16.00)
	184.69 (274.80)	0.75 (19.00)
	210.97 (313.90)	0.87 (22.00)
	236.45 (351.82)	0.98 (25.00)
	261.15 (388.57)	1.10 (28.00)
	292.86 (435.75)	1.26 (32.00)
	323.17 (480.84)	1.42 (36.00)
	352.08 (523.85)	1.57 (40.00)
26 by 18	174.51 (259.66)	0.63 (16.00)
(650.0 by 450.0)	204.74 (304.63)	0.75 (19.00)
	234.18 (348.44)	0.87 (22.00)
	262.83 (391.07)	0.98 (25.00)
	290.70 (432.53)	1.10 (28.00)
	326.63 (485.99)	1.26 (32.00)
	361.15 (537.36)	1.42 (36.00)
	394.28 (586.65)	1.57 (40.00)
30 by 20	199.84 (297.34)	0.63 (16.00)
(750.0 by 500.0)	234.81 (349.38)	0.75 (19.00)
	269.00 (400.25)	0.87 (22.00)
	302.40 (449.94)	0.98 (25.00)
	335.02 (498.47)	1.10 (28.00)
	377.27 (561.35)	1.26 (32.00)
	418.13 (622.14)	1.42 (36.00)
	457.59 (680.85)	1.57 (40.00)

19. Certification

19.1 When specified in the purchase order or contract, the manufacturer shall furnish to the purchaser a certificate of compliance stating that the product was manufactured, sampled, tested, and inspected in accordance with this specification and any other requirements designated in the purchase order or contract, and was found to meet all such requirements. Certificates of compliance shall include the specification number and year of issue.

19.2 When specified in the purchase order or contract, the manufacturer shall furnish to the purchaser test reports for the product shipped that contain the heat analyses and the results of the tension tests required by this specification and the purchase order or contract. Test reports shall include the specification number and year of issue.

19.3 A signature or notarization is not required on certificates of compliance or test reports; however, the documents shall clearly identify the organization submitting them. Notwithstanding the absence of a signature, the organization submitting the document is responsible for its content.

19.4 A certificate of compliance or test report printed from, or used in electronic form from, an electronic data interchange (EDI) shall be regarded as having the same validity as a counterpart printed in the certifying organization's facility. The content of the EDI transmitted document shall conform to any existing EDI agreement between the purchaser and the manufacturer.

TABLE 5 Dimensions of Common Sizes of Round Structural Tubing

NPS Designator	Outside Diameter, in. (mm)	Weight per Unit Length, lb/ft (kg/m)	Calculated Nominal Wall Thickness, in. (mm)
½	0.840 (21.3)	0.85 (1.27)	0.109 (2.77)
	0.840 (21.3)	1.09 (1.62)	0.147 (3.73)
¾	1.050 (26.7)	1.13 (1.69)	0.113 (2.87)
	1.050 (26.7)	1.47 (2.20)	0.154 (3.91)
1	1.315 (33.4)	1.34 (2.00)	0.104 (2.64)
	1.315 (33.4)	1.68 (2.50)	0.133 (3.38)
	1.315 (33.4)	2.17 (3.24)	0.179 (4.55)
1¼	1.660 (42.2)	1.82 (2.71)	0.110 (2.79)
	1.660 (42.2)	2.27 (3.39)	0.140 (3.56)
	1.660 (42.2)	3.00 (4.47)	0.191 (4.85)
1½	1.900 (48.3)	2.17 (3.25)	0.114 (2.90)
	1.900 (48.3)	2.72 (4.05)	0.145 (3.68)
	1.900 (48.3)	3.63 (5.41)	0.200 (5.08)
2	2.375 (60.3)	2.91 (4.33)	0.121 (3.07)
	2.375 (60.3)	3.65 (5.44)	0.154 (3.91)
	2.375 (60.3)	5.02 (7.48)	0.218 (5.54)
2½	2.875 (73.0)	4.53 (6.74)	0.156 (3.96)
	2.875 (73.0)	5.40 (8.04)	0.188 (4.78)
	2.875 (73.0)	5.79 (8.63)	0.203 (5.16)
	2.875 (73.0)	7.66 (11.41)	0.276 (7.01)
3	3.500 (88.9)	5.57 (8.29)	0.156 (3.96)
	3.500 (88.9)	6.65 (9.92)	0.188 (4.78)
	3.500 (88.9)	7.58 (11.29)	0.216 (5.49)
	3.500 (88.9)	10.25 (15.27)	0.300 (7.62)
3½	4.000 (101.6)	6.40 (9.53)	0.156 (3.96)
	4.000 (101.6)	7.65 (11.41)	0.188 (4.78)
	4.000 (101.6)	9.11 (13.57)	0.226 (5.74)
	4.000 (101.6)	12.50 (18.63)	0.318 (8.08)
4	4.500 (114.3)	7.24 (10.78)	0.156 (3.96)
	4.500 (114.3)	8.66 (12.91)	0.188 (4.78)
	4.500 (114.3)	10.01 (14.91)	0.219 (5.56)
	4.500 (114.3)	10.79 (16.07)	0.237 (6.02)
	4.500 (114.3)	14.98 (22.32)	0.337 (8.56)
5	5.563 (141.3)	14.62 (21.77)	0.258 (6.55)
	5.563 (141.3)	20.78 (30.97)	0.375 (9.53)
	5.563 (141.3)	38.55 (57.43)	0.750 (19.05)
6	6.625 (168.3)	18.97 (28.26)	0.280 (7.11)
	6.625 (168.3)	28.57 (42.56)	0.432 (10.97)
	6.625 (168.3)	53.16 (79.22)	0.864 (21.95)
8	8.625 (219.1)	28.55 (42.55)	0.322 (8.18)
	8.625 (219.1)	43.39 (64.64)	0.500 (12.70)
	8.625 (219.1)	72.42 (107.92)	0.875 (22.23)
10	10.750 (273.0)	40.48 (60.31)	0.365 (9.27)
	10.750 (273.0)	54.74 (81.55)	0.500 (12.70)
	10.750 (273.0)	104.13 (155.15)	1.000 (25.40)
12	12.750 (323.8)	49.56 (73.88)	0.375 (9.53)
	12.750 (323.8)	65.42 (97.46)	0.500 (12.70)
	12.750 (323.8)	125.49 (186.97)	1.000 (25.40)
14	14.000 (355.6)	54.57 (81.33)	0.375 (9.53)
	14.000 (355.6)	72.09 (107.39)	0.500 (12.70)
16	16.000 (406.4)	62.58 (93.27)	0.375 (9.53)
	16.000 (406.4)	82.77 (123.30)	0.500 (12.70)
18	18.000 (457.2)	70.59 (105.16)	0.375 (9.53)
	18.000 (457.2)	93.45 (139.15)	0.500 (12.70)
20	20.000 (508.0)	78.60 (117.15)	0.375 (9.53)
	20.000 (508.0)	104.13 (155.12)	0.500 (12.70)
24	24.000 (609.6)	94.62 (141.12)	0.375 (9.53)
	24.000 (609.6)	125.49 (187.06)	0.500 (12.70)

20. Product Marking

20.1 Except as allowed by 20.2, each length of structural tubing shall be legibly marked by rolling, die-stamping, ink printing, or paint stenciling to show the following information:

TABLE 6 Permissible Variations in Outside Flat Dimensions for Square, Rectangular, and Special Shape Structural Tubing

Specified Outside Large Flat Dimension, in. (mm)	Permissible Variations Over and Under Specified Outside Flat Dimensions,[A] in. (mm)
2½ (63.5) and under	0.020 (0.51)
Over 2½ to 3½ (63.5 to 88.9), incl	0.025 (0.64)
Over 3½ to 5½ (88.9 to 139.7), incl	0.030 (0.76)
Over 5½ (139.7) to 10 (254), incl	0.01 times large flat dimension
Over 10 (254)	0.02 times large flat dimension

[A] The permissible variations include allowances for convexity and concavity.

TABLE 7 Permissible Variations in Length for Specific Lengths of Structural Tubing

	22 ft (6.7 m) and Under		Over 22 to 44 ft (6.7 to 13.4 m), incl	
	Over	Under	Over	Under
Permissible variations in length for specific lengths, in. (mm)	½ (12.7)	¼ (6.4)	¾ (19.0)	¼ (6.4)

TABLE 8 Permissible Variations in Twist for Square, Rectangular, and Special Shape Structural Tubing

Specified Outside Large Flat Dimension, in. (mm)	Maximum Permissible Variations in Twist per 3 ft of Length (Twist per Metre of Length)	
	in.	mm
1½ (38.1) and under	0.050	1.39
Over 1½ to 2½ (38.1 to 63.5), incl	0.062	1.72
Over 2½ to 4 (63.5 to 101.6), incl	0.075	2.09
Over 4 to 6 (101.6 to 152.4), incl	0.087	2.42
Over 6 to 8 (152.4 to 203.2), incl	0.100	2.78
Over 8 (203.2)	0.112	3.11

manufacturer's name, brand, or trademark; size; and the specification designation (year of issue not required).

20.2 For structural tubing having a specified outside diameter or large flat dimension less than 2 in. (50.8 mm), it shall be permissible for the information listed in 20.1 to be marked on a tag securely attached to each bundle.

20.3 *Bar Coding*—In addition to the requirements in 20.1 and 20.2, the manufacturer shall have the option of using bar coding as a supplementary identification method. When a specific bar coding system is specified in the purchase order, that system shall be used.

NOTE 2—In the absence of another bar coding system being specified in the purchase order, it is recommended that bar coding be consistent with AIAG Standard B-1.

21. Packaging, Marking, and Loading

21.1 When specified in the purchase order, packaging, marking, and loading shall be in accordance with Practices A 700.

22. Keywords

22.1 steel tube; structural steel tubing

SUPPLEMENTARY REQUIREMENTS

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

S1. Weld Line Integrity Evaluation

S1.1 The weld line integrity evaluation applies to Grade B only.

If NDT of the weld line is an express requirement of an order, 100 % of the weld line shall be subjected to nondestructive testing via eddy current or ultrasonic techniques. The technique, as well as acceptance criteria, shall be agreed upon by the purchaser and manufacturer, and specified on the order.

NOTE S1—Eddy current equipment usage is limited by its maximum thickness measurement capabilities.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 501 – 01(2005), that may impact the use of this specification.

(*1*) Revised 1.2. Added new 1.3 and 1.4 and renumbered subsequent paragraphs.

(*2*) Added new 4.1.3 and renumbered subsequent paragraphs. Revised 6.1.

(*3*) Replaced old Section 10 Bend Test with new Section 10 Charpy V-Notch Impact Test.

(*4*) Added Supplementary Requirement.

(*5*) Deleted old Table 3 and renumbered subsequent tables. Revised Table 1, Table 2, Table 3, Table 4, and Table 6.

Designation: A 500/A 500M – 07

Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes[1]

This standard is issued under the fixed designation A 500/A 500M; 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*

1.1 This specification covers cold-formed welded and seamless carbon steel round, square, rectangular, or special shape structural tubing for welded, riveted, or bolted construction of bridges and buildings, and for general structural purposes.

1.2 This tubing is produced in both welded and seamless sizes with a periphery of 64 in. [1630 mm] or less, and a specified wall thickness of 0.625 in. [16 mm] or less. Grade D requires heat treatment.

NOTE 1—Products manufactured to this specification may not be suitable for those applications such as dynamically loaded elements in welded structures, etc., where low-temperature notch-toughness properties may be important.

1.3 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.

1.4 The text of this specification contains notes and footnotes that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

2.2 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[3]

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage[3]

2.3 *Federal Standards:*

Fed. Std. No. 123 Marking for Shipment[3]

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products[3]

2.4 *AIAG Standard:*

B-1 Bar Code Symbology Standard[4]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A 941.

4. Ordering Information

4.1 Orders for material under this specification shall contain information concerning as many of the following items as are required to describe the desired material adequately:

4.1.1 Quantity (feet [metres] or number of lengths),

4.1.2 Name of material (cold-formed tubing),

4.1.3 Method of manufacture (seamless or welded),

4.1.4 Grade (A, B, C, or D),

4.1.5 Size (outside diameter and wall thickness for round tubing, and outside dimensions and wall thickness for square and rectangular tubing),

4.1.6 Copper-containing steel (see Table 1), if applicable,

4.1.7 Length (random, multiple, specific; see 11.3),

4.1.8 End condition (see 16.3),

4.1.9 Burr removal (see 16.3),

4.1.10 Certification (see Section 18),

4.1.11 ASTM specification designation and year of issue,

4.1.12 End use,

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Sept. 1, 2007. Published October 2007. Originally approved in 1964. Last previous edition approved in 2003 as A 500-03a.

[2] 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.

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[4] Available from Automotive Industry Action Group (AIAG), 26200 Lahser Rd., Suite 200, Southfield, MI 48033, http://www.aiag.org.

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

TABLE 1 Chemical Requirements

Element	Composition, %			
	Grades A, B, and D		Grade C	
	Heat Analysis	Product Analysis	Heat Analysis	Product Analysis
Carbon, max[A]	0.26	0.30	0.23	0.27
Manganese, max[A]	1.35	1.40	1.35	1.40
Phosphorus, max	0.035	0.045	0.035	0.045
Sulfur, max	0.035	0.045	0.035	0.045
Copper, min[B]	0.20	0.18	0.20	0.18

[A] For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 % by heat analysis and 1.60 % by product analysis.
[B] If copper-containing steel is specified in the purchase order.

4.1.13 Special requirements, and
4.1.14 Bar coding (see 19.3).

5. Process

5.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

5.2 When steels of different grades are sequentially strand cast, the steel producer shall identify the resultant transition material and remove it using an established procedure that positively separates the grades.

6. Manufacture

6.1 The tubing shall be made by a seamless or welding process.

6.2 Welded tubing shall be made from flat-rolled steel by the electric-resistance-welding process. The longitudinal butt joint of welded tubing shall be welded across its thickness in such a manner that the structural design strength of the tubing section is assured.

NOTE 2—Welded tubing is normally furnished without removal of the inside flash.

6.3 Except as required by 6.4, it shall be permissible for the tubing to be stress relieved or annealed.

6.4 Grade D tubing shall be heat treated at a temperature of at least 1100 °F [590 °C] for one hour per inch [25 mm] of thickness.

7. Heat Analysis

7.1 Each heat analysis shall conform to the requirements specified in Table 1 for heat analysis.

8. Product Analysis

8.1 The tubing shall be capable of conforming to the requirements specified in Table 1 for product analysis.

8.2 If product analyses are made, they shall be made using test specimens taken from two lengths of tubing from each lot of 500 lengths, or fraction thereof, or two pieces of flat-rolled stock from each lot of a corresponding quantity of flat-rolled stock. Methods and practices relating to chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751. Such product analyses shall conform to the requirements specified in Table 1 for product analysis.

8.3 If both product analyses representing a lot fail to conform to the specified requirements, the lot shall be rejected.

8.4 If only one product analysis representing a lot fails to conform to the specified requirements, product analyses shall be made using two additional test specimens taken from the lot. Both additional product analyses shall conform to the specified requirements or the lot shall be rejected.

9. Tensile Requirements

9.1 The material, as represented by the test specimen, shall conform to the requirements as to tensile properties prescribed in Table 2.

10. Flattening Test

10.1 The flattening test shall be made on round structural tubing. A flattening test is not required for shaped structural tubing.

10.2 For welded round structural tubing, a test specimen at least 4 in. [100 mm] in length shall be flattened cold between parallel plates in three steps, with the weld located 90° from the line of direction of force. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces of the test specimen shall be present until the distance between the plates is less than two-thirds of the specified outside diameter of the tubing. For the second step, no cracks or breaks on the inside or outside parent metal surfaces of the test specimen, except as provided for in 10.5, shall be present until the distance between the plates is less than one-half of the specified outside diameter of the tubing. During the third step, which is a test for soundness, the flattening shall be continued until the test specimen breaks or the opposite walls of the test specimen meet. Evidence of

TABLE 2 Tensile Requirements

Round Structural Tubing				
	Grade A	Grade B	Grade C	Grade D
Tensile strength, min, psi [MPa]	45 000 [310]	58 000 [400]	62 000 [425]	58 000 [400]
Yield strength, min, psi [MPa]	33 000 [230]	42 000 [290]	46 000 [315]	36 000 [250]
Elongation in 2 in. [50 mm], min, %[D]	25[A]	23[B]	21[C]	23[B]
Shaped Structural Tubing				
	Grade A	Grade B	Grade C	Grade D
Tensile strength, min, psi [MPa]	45 000 [310]	58 000 [400]	62 000 [425]	58 000 [400]
Yield strength, min, psi [MPa]	39 000 [270]	46 000 [315]	50 000 [345]	36 000 [250]
Elongation in 2 in. [50 mm], min, %[D]	25[A]	23[B]	21[C]	23[B]

[A] Applies to specified wall thicknesses (t) equal to or greater than 0.120 in. [3.05 mm]. For lighter specified wall thicknesses, the minimum elongation values shall be calculated by the formula: percent elongation in 2 in. [50 mm] = $56t + 17.5$, rounded to the nearest percent.
[B] Applies to specified wall thicknesses (t) equal to or greater than 0.180 in. [4.57 mm]. For lighter specified wall thicknesses, the minimum elongation values shall be calculated by the formula: percent elongation in 2 in. [50 mm] = $61t + 12$, rounded to the nearest percent.
[C] Applies to specified wall thicknesses (t) equal to or greater than 0.120 in. [3.05 mm]. For lighter specified wall thicknesses, the minimum elongation values shall be by agreement with the manufacturer.
[D] The minimum elongation values specified apply only to tests performed prior to shipment of the tubing.

laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

10.3 For seamless round structural tubing 2⅜ in. [60 mm] specified outside diameter and larger, a specimen not less than 2½ in. [65 mm] in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, no cracks or breaks on the inside or outside surfaces, except as provided for in 10.5, shall occur until the distance between the plates is less than the value of "H" calculated by the following equation:

$$H = (1 + e)t / (e + t / D) \tag{1}$$

where:

H = distance between flattening plates, in. [mm],
e = deformation per unit length (constant for a given grade of steel, 0.09 for Grade A, 0.07 for Grade B, and 0.06 for Grade C),
t = specified wall thickness of tubing, in. [mm], and
D = specified outside diameter of tubing, in. [mm].

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the specimen meet. Evidence of laminated or unsound material that is revealed during the entire flattening test shall be cause for rejection.

10.4 Surface imperfections not found in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with Section 15.

10.5 When low *D*-to-*t* ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at these locations shall not be cause for rejection if the *D*-to-*t* ratio is less than 10.

11. Permissible Variations in Dimensions

11.1 *Outside Dimensions*:

11.1.1 *Round Structural Tubing*—The outside diameter shall not vary more than ±0.5 %, rounded to the nearest 0.005 in. [0.1 mm], from the specified outside diameter for specified outside diameters 1.900 in. [48 mm] and smaller, and ± 0.75 %, rounded to the nearest 0.005 in. [0.1 mm], from the specified outside diameter for specified outside diameters 2.00 in. [5 cm] and larger. The outside diameter measurements shall be made at positions at least 2 in. [5 cm] from the ends of the tubing.

11.1.2 *Square and Rectangular Structural Tubing*—The outside dimensions, measured across the flats at positions at least 2 in. [5 cm] from the ends of the tubing, shall not vary from the specified outside dimensions by more than the applicable amount given in Table 3, which includes an allowance for convexity or concavity.

11.2 *Wall Thickness*—The minimum wall thickness at any point of measurement on the tubing shall be not more than 10 % less than the specified wall thickness. The maximum wall thickness, excluding the weld seam of welded tubing, shall be not more than 10 % greater than the specified wall thickness. For square and rectangular tubing, the wall thickness requirements shall apply only to the centers of the flats.

TABLE 3 Permissible Variations in Outside Flat Dimensions for Square and Rectangular Structural Tubing

Specified Outside Large Flat Dimension, in. [mm]	Permissible Variations Over and Under Specified Outside Flat Dimensions,[A] in. [mm]
2½ [65] or under	0.020 [0.5]
Over 2½ to 3½ [65 to 90], incl	0.025 [0.6]
Over 3½ to 5½ [90 to 140], incl	0.030 [0.8]
Over 5½ [140]	0.01 times large flat dimension

[A] The permissible variations include allowances for convexity and concavity. For rectangular tubing having a ratio of outside large to small flat dimension less than 1.5, and for square tubing, the permissible variations in small flat dimension shall be identical to the permissible variations in large flat dimension. For rectangular tubing having a ratio of outside large to small flat dimension in the range of 1.5 to 3.0 inclusive, the permissible variations in small flat dimension shall be 1.5 times the permissible variations in large flat dimension. For rectangular tubing having a ratio of outside large to small flat dimension greater than 3.0, the permissible variations in small flat dimension shall be 2.0 times the permissible variations in large flat dimension.

11.3 *Length*—Structural tubing is normally produced in random lengths 5 ft [1.5 m] and over, in multiple lengths, and in specific lengths. Refer to Section 4. When specific lengths are ordered, the length tolerance shall be in accordance with Table 4.

11.4 *Straightness*—The permissible variation for straightness of structural tubing shall be ⅛ in. times the number of feet [10 mm times the number of metres] of total length divided by 5.

11.5 *Squareness of Sides*—For square and rectangular structural tubing, adjacent sides shall be square (90°), with a permissible variation of ±2° max.

11.6 *Radius of Corners*—For square and rectangular structural tubing, the radius of each outside corner of the section shall not exceed three times the specified wall thickness.

11.7 *Twist*—For square and rectangular structural tubing, the permissible variations in twist shall be as given in Table 5. Twist shall be determined by holding one end of the tubing down on a flat surface plate, measuring the height that each corner on the bottom side of the tubing extends above the surface plate near the opposite ends of the tubing, and calculating the twist (the difference in heights of such corners), except that for heavier sections it shall be permissible to use a suitable measuring device to determine twist. Twist measurements shall not be taken within 2 in. [5 cm] of the ends of the tubing.

12. Special Shape Structural Tubing

12.1 The availability, dimensions, and tolerances of special shape structural tubing shall be subject to inquiry and negotiation with the manufacturer.

TABLE 4 Length Tolerances for Specific Lengths of Structural Tubing

	22 ft [6.5 m] and Under		Over 22 ft [6.5 m]	
	Over	Under	Over	Under
Length tolerance for specific lengths, in. [mm]	½ [13]	¼ [6]	¾ [19]	¼ [6]

TABLE 5 Permissible Variations in Twist for Square and Rectangular Structural Tubing

Specified Outside Large Flat Dimension, in. [mm]	Maximum Permissible Variations in Twist per 3 ft of Length [Twist per Metre of Length]	
	in.	[mm]
1½ [40] and under	0.050	[1.3]
Over 1½ to 2½ [40 to 65], incl	0.062	[1.6]
Over 2½ to 4 [65 to 100], incl	0.075	[1.9]
Over 4 to 6 [100 to 150], incl	0.087	[2.2]
Over 6 to 8 [150 to 200], incl	0.100	[2.5]
Over 8 [200]	0.112	[2.8]

13. Number of Tests

13.1 One tension test as specified in Section 15 shall be made from a length of tubing representing each lot.

13.2 The flattening test, as specified in Section 10, shall be made on one length of round tubing from each lot.

13.3 The term "lot" shall apply to all tubes of the same specified size that are produced from the same heat of steel.

14. Retests

14.1 If the results of the mechanical tests representing any lot fail to conform to the applicable requirements specified in Sections 9 and 10, the lot shall be rejected or retested using additional tubing of double the original number from the lot. The lot shall be acceptable if the results of all such retests representing the lot conform to the specified requirements.

14.2 If one or both of the retests specified in 14.1 fail to conform to the applicable requirements specified in Sections 9 and 10, the lot shall be rejected or, subsequent to the manufacturer heat treating, reworking, or otherwise eliminating the condition responsible for the failure, the lot shall be treated as a new lot and tested accordingly.

15. Test Methods

15.1 Tension test specimens shall conform to the applicable requirements of Test Methods and Definitions A 370, Annex A2.

15.2 Tension test specimens shall be full–size longitudinal test specimens or longitudinal strip test specimens. For welded tubing, any longitudinal strip test specimens shall be taken from a location at least 90° from the weld and shall be prepared without flattening in the gage length. Longitudinal strip test specimens shall have all burrs removed. Tension test specimens shall not contain surface imperfections that would interfere with proper determination of the tensile properties.

15.3 The yield strength corresponding to an offset of 0.2 % of the gage length or to a total extension under load of 0.5 % of the gage length shall be determined.

16. Inspection

16.1 All tubing shall be inspected at the place of manufacture to ensure conformance to the requirements of this specification.

16.2 All tubing shall be free from defects and shall have a workmanlike finish.

16.2.1 Surface imperfections shall be classed as defects when their depth reduces the remaining wall thickness to less than 90 % of the specified wall thickness. It shall be permissible for defects having a depth not in excess of 33⅓ % of the specified wall thickness to be repaired by welding, subject to the following conditions:

16.2.1.1 The defect shall be completely removed by chipping or grinding to sound metal,

16.2.1.2 The repair weld shall be made using a low-hydrogen welding process, and

16.2.1.3 The projecting weld metal shall be removed to produce a workmanlike finish.

16.2.2 Surface imperfections such as handling marks, light die or roll marks, or shallow pits are not considered defects provided that the imperfections are removable within the specified limits on wall thickness. The removal of such surface imperfections is not required. Welded tubing shall be free of protruding metal on the outside surface of the weld seam.

16.3 Unless otherwise specified in the purchase order, structural tubing shall be furnished with square cut ends, with the burr held to a minimum. When so specified in the purchase order, the burr shall be removed on the outside diameter, inside diameter, or both.

17. Rejection

17.1 It shall be permissible for the purchaser to inspect tubing received from the manufacturer and reject any tubing that does not meet the requirements of this specification, based upon the inspection and test methods outlined herein. The purchaser shall notify the manufacturer of any tubing that has been rejected, and the disposition of such tubing shall be subject to agreement between the manufacturer and the purchaser.

17.2 It shall be permissible for the purchaser to set aside any tubing that is found in fabrication or installation within the scope of this specification to be unsuitable for the intended end use, based on the requirements of this specification. The purchaser shall notify the manufacturer of any tubing that has been set aside. Such tubing shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. The disposition of such tubing shall be subject to agreement between the manufacturer and the purchaser.

18. Certification

18.1 When specified in the purchase order or contract, the manufacturer shall furnish to the purchaser a certificate of compliance stating that the product was manufactured, sampled, tested, and inspected in accordance with this specification and any other requirements designated in the purchase order or contract, and was found to meet all such requirements. Certificates of compliance shall include the specification number and year of issue.

18.2 When specified in the purchase order or contract, the manufacturer shall furnish to the purchaser test reports for the product shipped that contain the heat analyses and the results of the tension tests required by this specification and the purchase order or contract. Test reports shall include the specification number and year of issue.

18.3 A signature or notarization is not required on certificates of compliance or test reports; however, the documents shall clearly identify the organization submitting them. Notwithstanding the absence of a signature, the organization submitting the document is responsible for its content.

18.4 A certificate of compliance or test report printed from, or used in electronic form from, an electronic data interchange (EDI) shall be regarded as having the same validity as a counterpart printed in the certifying organization's facility. The content of the EDI transmitted document shall conform to any existing EDI agreement between the purchaser and the manufacturer.

19. Product Marking

19.1 Except as noted in 19.2, each length of structural tubing shall be legibly marked to show the following information: manufacturer's name, brand, or trademark; the specification designation (year of issue not required); and grade letter.

19.2 For structural tubing having a specified outside diameter or large flat dimension of 4 in. [10 cm] or less, it shall be permissible for the information listed in 19.1 to be marked on a tag securely attached to each bundle.

19.3 *Bar Coding*—In addition to the requirements in 19.1 and 19.2, the manufacturer shall have the option of using bar coding as a supplementary identification method. When a specific bar coding system is specified in the purchase order, that system shall be used.

NOTE 3—In the absence of another bar coding system being specified in the purchase order, it is recommended that bar coding be consistent with AIAG Standard B-1.

20. Packing, Marking, and Loading

20.1 When specified in the purchase order, packaging, marking, and loading shall be in accordance with Practices A 700.

21. Government Procurement

21.1 When specified in the contract, material shall be preserved, packaged and packed in accordance with the requirements of MIL-STD 163, with applicable levels being specified in the contract. Marking for shipment of such materials shall be in accordance with Federal Std. No. 123 for civil agencies and MIL-STD 129 or Federal Std. No. 183 if continuous marking is required.

21.2 *Inspection*—Unless otherwise specified in the contract, the manufacturer shall be responsible for the performance of all applicable inspection and test requirements specified herein. Except as otherwise specified in the contract, the manufacturer shall use its own or any other suitable facilities for the performance of such inspections and tests.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 500 – 03a, that may impact the use of this specification. (Approved September 1, 2007)

(*1*) The standard was revised as a dual units specification.

Designation: A 498 – 06

Standard Specification for Seamless and Welded Carbon Steel Heat-Exchanger Tubes with Integral Fins[1]

This standard is issued under the fixed designation A 498; 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 covers external helical, integral finned, seamless or welded low-carbon steel tubes for use in tubular heat exchangers, surface condensers, evaporators, superheaters, and similar heat-transfer apparatus in unfinned end diameters up to 2 in. (50.8 mm), inclusive.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 179/A 179M Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes

A 214/A 214M Specification for Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes

A 334/A 334M Specification for Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service

3. Ordering Information

3.1 The purchaser shall specify in the order the plain-tube specification and the alloy from which the finned tube is to be manufactured.

3.2 The purchaser shall specify in the order the diameter, wall thickness, and length of unfinned sections; root diameter and wall thickness of the finned section; number of fins per unit length; and the total tube length.

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Oct. 1, 2006. Published October 2006. Originally approved in 1963. Last previous edition approved in 2004 as A 498 – 04.

[2] 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. Material and Manufacture

4.1 The finned tubes shall be manufactured from plain tubes that conform to one of the following Specifications: A 179/A 179M, A 214/A 214M, or A 334/A 334M.

4.2 Any tests that are required in the plain-tube specifications that are performed on unfinned lengths of tube in accordance with this specification need not be performed on the plain tube.

4.3 The fins shall be produced by the cold forming of steel prime-surface tube. To comply with this specification, the fin and tube material must be homogeneous.

4.4 Finned tubes shall normally be furnished with unfinned ends, but may be furnished with finned ends if specified.

5. Heat Treatment

5.1 The tube after finning shall be supplied in either the *annealed* or *as-fabricated* condition, one of which shall be specified on the purchaser order.

5.2 The annealed condition is defined as having both the finned and unfinned portions of the tube conforming to the applicable heat-treatment requirements of the governing ASTM specification for the steel tube analysis involved.

5.3 The as-fabricated condition is defined as having the finned portions of the tube in the *as-finned* or cold-worked condition produced by the finning operation and the unfinned or plain tube portions of the finned tube in the as-fabricated condition suitable for rolling-in operations.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements prescribed in the governing plain-tube specification.

7. Tensile Requirements

7.1 The tube prior to the finning operation, or unfinned portions of the finned tube, shall conform to the requirements for tensile properties prescribed in the governing plain-tube specification.

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

8. Pressure Test

8.1 Each tube after finning shall be subjected to an internal air pressure of 250 psi (1.72 MPa) minimum for 5 s without showing evidence of leakage. Any evidence of leakage shall be cause for rejection. The test method used shall permit easy visual detection of any leakage, such as testing the tube under water or by the pressure differential method.[3]

9. Dimensions and Permissible Variations

9.1 *Diameter*—The outside diameter of the unfinned sections shall not exceed the diameter tolerances as specified in the governing prime-surface tube specification (see Fig. 1).

9.2 *Wall Thickness*—No tube at its thinnest point beneath the fins or in the plain section shall be less than the minimum thickness specified.

9.3 *Length*—The length of the tubes shall not be less than that specified when measured at a temperature of 68 °F (20 °C), but may exceed the specified value by the amounts given in Table 1.

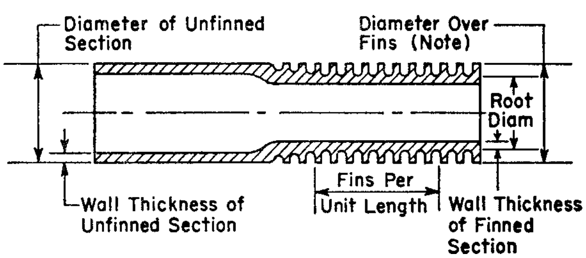
TABLE 1 Tolerances for Specified Length of Tubes

Specified Length, ft (m)	Tolerance, in. (mm)
Up to 24 (7.3), incl	+1⁄8 (3.2)
Over 24 to 34 (7.3 to 10.4), incl	+1⁄4 (6.4)
Over 34 to 44 (10.4 to 13.4), incl	+3⁄8 (9.5)
Over 44 (13.4)	+1⁄2 (12.7) max

10. Workmanship and Finish

10.1 Finished tubes shall be reasonably straight and have smooth ends free from burrs. They shall be free from injurious defects and shall have a workmanlike finish. A slight amount of oxidation will not be considered as scale.

[3] The pressure differential method is described in *ASTM Material Research Standards*, ASTM, Vol 1, No. 7, July 1961.



NOTE 1—The diameter over the fins will not normally exceed the diameter of the unfinned section.

FIG. 1 Finned Tube Nomenclature

11. Package Marking

11.1 The name or brand of the manufacturer, name and order number of the purchaser, plain tube specification, condition (annealed or as-fabricated), Specification A 498 tube diameter, wall thickness, and tube length shall be marked on a tag securely attached to the bundle or box in which the tubes are shipped. The marking need not include the year of issue of the specification.

11.2 *Bar Coding*—In addition to the requirements stated in 11.1, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

12. Inspection

12.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

12.2 *Certification*—When specified in the purchase order or contract, the manufacturer shall furnish a dated report certifying that the material was manufactured, sampled, tested, and inspected in accordance with the requirements of this specification, including the year of issue of the specification.

13. Rejection

13.1 Any rejection based on tests made in accordance with this specification, and those allowed by the governing plain-tube specification, shall be reported to the manufacturer. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

13.2 Material that fails in the process of installation shall be set aside and the manufacturer notified for mutual evaluation of suitability of the material. Disposition of such material shall be a matter for agreement.

14. Keywords

14.1 carbon steel tube; heat exchanger tube; seamless steel tube; steel tube; welded steel tube

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 498 – 04, that may impact the use of this specification. (Approved October 1, 2006)

(*1*) Added Specification A 334/A 334M to paragraph 4.1.

Designation: A 453/A 453M – 04

Standard Specification for High-Temperature Bolting Materials, with Expansion Coefficients Comparable to Austenitic Stainless Steels[1]

This standard is issued under the fixed designation A 453/A 453M; 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*

1.1 This specification[2] covers four grades of bolting materials with ten classes of yield strength ranging from 50 to 120 ksi [345 to 827 MPa] for use in high-temperature service such as fasteners for pressure vessel and valve flanges. The material requires special processing and is not intended for general purpose applications. The term "bolting material," as used in this specification, covers rolled, forged, or hot-extruded bars; bolts, nuts, screws, washers, studs, and stud bolts. Headed bolts and rolled threads may be supplied.

NOTE 1—Other bolting materials are covered by Specification A 193/A 193M and Specification A 437/A 437M.

1.2 Supplementary Requirement S 1 of an optional nature is provided. This shall apply only when specified by the purchaser in the order.

1.3 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

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.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service

A 437/A 437M Specification for Alloy-Steel Turbine-Type Bolting Material Specially Heat Treated for High-Temperature Service

A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range

E 139 Test Method for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *bolting material*—this covers rolled, forged, or hot-extruded bars; bolts, nuts, screws, washers, studs, and stud bolts; and also includes those manufactured by upset heading or roll threading techniques.

3.1.2 *heat-treatment charge*—one heat of material heat treated in one batch. If a continuous operation is used, the weight processed as a heat-treatment charge shall not exceed the weights in Table 1.

3.1.3 *lot*—a lot shall consist of the quantities shown in Table 2.

4. Ordering Information

4.1 The inquiry and order shall indicate the following:

4.1.1 Quantity (weight or number of pieces),

4.1.2 Description of material (bars, bolts, nuts, etc.),

4.1.3 Grade and class (see Table 3),

4.1.4 Method of finishing (see 6.1),

4.1.5 Type of thread desired (see 6.1.1),

4.1.6 Alternative test method option (see 7.2.4.3),

4.1.7 Bolt shape option, if any,

4.1.8 Thread option, if any,

4.1.9 Test method for surface quality, if any,

4.1.10 Test location option, if any,

4.1.11 Rejection option, if any, and

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved Oct. 1, 2004. Published October 2004. Originally approved in 1961. Last previous edition approved in 2003 as A 453/A 453M – 03.

[2] For ASME Boiler and Pressure Vessel Code Applications see related Specification SA-453 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.

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

TABLE 1 Continuous Heat-Treatment Charge Sizes

Diameter, in. [mm]	Weight, lb [kg]
To 1¾ [44]	3000 [1400]
Over 1¾ [44] to 2½ [63]	6000 [2700]
Over 2½ [63]	12000 [5400]

TABLE 2 Lot Sizes

Diameter, in. [mm]	Maximum Lot Size, lb [kg]
1½ [38] and under	200 [90]
Over 1½ [38] to 1¾ [44], incl	300 [140]
Over 1¾ [44] to 2½ [63], incl	600 [270]
Over 2½ [63]	20 pieces

4.1.12 If stress-rupture testing is not required, except for Grade 660 Class D (see 7.2.1).

5. Common Requirements

5.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 962/A 962M, this specification shall prevail.

6. Materials and Manufacture

6.1 *Finishing Process*:

6.1.1 Threads may be performed by machining or rolling. For Type 1 bolting, threading shall be performed after precipitation heat treatment. Types M1 and M2 bolting shall have machine cut threads. For Types 2 R1 and R2, bolting shall have rolled threads. Types R1 and M1 bolting, threading shall be performed after precipitation heat treatment. Types R2 and M2 bolting shall be threaded after solution heat treatment but prior to precipitation heat treatment. When not specified by the purchaser, the type supplied shall be the option of the manufacturer.

6.2 *Heat Treatment*—Each grade and class shall be heat treated as prescribed in Table 4.

7. Mechanical Properties

7.1 *Tension Test*:

7.1.1 *Requirements*—The material in each heat-treatment charge shall conform to the room-temperature tensile requirements in Table 5.

7.1.2 *Number of Specimens*:

7.1.2.1 *Heat-Treated Bars*—When not more than two sizes of bars are heat treated in the same load, one tension test shall be made from each size in each heat of material in the heat-treatment charge (see 3.1.2). When more than two sizes of bars are treated in the same charge, one tension test shall be made from one bar of each of the two largest diameters from each heat of material in the heat-treating charge.

7.1.2.2 *Finished Parts*—One tension test shall be made if the lot consists of parts of the same nominal diameter. If the lot consists of parts of more than one nominal diameter, one tension test shall be made from each nominal diameter of each heat involved in the lot (see Section 3).

7.1.2.3 The diameter range shall be in increments of ½ in. [12.5 mm].

7.2 *Stress-Rupture Test*:

7.2.1 *Requirements*—The material shall conform to the stress-rupture requirements prescribed in Table 6 for design temperatures above 800 °F [427 °C]. Material not stress-rupture tested shall be permanently stamped NR. Grade 660 Class D does not require stress-rupture and shall be stamped NR.

7.2.2 The number of specimens shall be the same as the required number of tension test specimens.

7.2.3 The test location and orientation shall be the same as that required for the tension test specimens.

7.2.4 *Test Method*:

7.2.4.1 The rupture test shall be performed in accordance with Practice E 139.

7.2.4.2 A combination smooth and notched test specimen, machined to the dimensions prescribed in Fig. 1 and Table 7, shall be tested in accordance with the stress-rupture requirements prescribed in Table 6. The test shall be continued to rupture. The rupture shall occur in the smooth section of the bar.

7.2.4.3 As an alternative procedure and, when specifically approved by the purchaser, separate smooth and notched test specimens, machined from adjacent sections of the same piece, with gage sections conforming to the respective dimensions of Table 7, may be tested under the above conditions. The notched specimen need not be tested to rupture but shall not rupture in less time than the companion smooth specimen.

7.2.4.4 When the minimum specified time to rupture in Table 6 has been achieved, incremental loading may be used to accelerate the time to rupture. At intervals of 8 to 16 h, preferably 8 to 10 h, the stress shall be increased in increments of 5000 psi [34.5 MPa]. Rupture location, and elongation requirements shall be as prescribed in Table 6, 7.2.4.2, and 7.2.4.3.

7.3 *Hardness Test*:

7.3.1 *Requirements*—The material shall conform to the room temperature hardness requirements prescribed in Table 5. For Grade 660 Class D, in the case of conflict, tensile test results shall prevail over minimum hardness.

7.3.2 *Number of Tests*:

7.3.2.1 *Bars 2 in. [50 mm] and Over*—One test on each mill-treated length.

7.3.2.2 *Bars under 2 in. [50 mm]*—One test on at least 10 % of the mill treated lengths.

7.3.2.3 *Fasteners*—One test each on two fasteners or on a sample per Guide F 1470, Table 3, sample size B for each heat lot, whichever is the larger sample.

7.3.3 *Test Locations*—The hardness test shall be made at the center of the cross section for bars up to 1 in. [25 mm] in diameter, and at the midradius on bars 1 in. [25 mm] and larger in diameter.

TABLE 3 Chemical Requirements

	Grade 660		Grade 651	
UNS Number	S66286		S63198	
	Content, %	Product Analysis Variation, Over or Under, %	Content, %	Product Analysis Variation, Over or Under, %
Carbon	0.08 max	0.01 over	0.28–0.35	0.02
Manganese	2.00 max	0.04	0.75–1.50	0.04
Phosphorus	0.040 max	0.005 over	0.040 max	0.005 over
Sulfur	0.030 max	0.005 over	0.030 max	0.005 over
Silicon	1.00 max	0.05	0.30–0.80	0.05
Nickel	24.0–27.0	0.20	8.0–11.0	0.15
Chromium	13.5–16.0	0.20	18.0–21.0	0.25
Molybdenum	1.00–1.50	0.05	1.00–1.75	0.05
Tungsten	...	...	1.00–1.75	0.05
Titanium	1.90–2.35	0.05	0.10–0.35	0.05 over
Columbium[A]	...	...	0.25–0.60	0.05
Aluminum	0.35 max	0.05 over	...	...
Vanadium	0.10–0.50	0.03	...	...
Boron	0.001–0.010	0.0004 under to 0.001 over	...	...
Copper	...	...	0.50 max	0.03 over
	Grade 662		Grade 665	
UNS Number	S66220		S66545	
	Content, %	Product Analysis, Variation Over or Under, %	Content, %	Product Analysis Variation, Over or Under, %
Carbon	0.08 max	0.01 over	0.08 max	0.01 over
Manganese	0.40–1.00	0.03	1.25–2.00	0.04
Phosphorus	0.040 max	0.005 over	0.040 max	0.005 over
Sulfur	0.030 max	0.005 over	0.030 max	0.005 over
Silicon	0.40–1.00	0.05	0.10–0.80	0.05
Nickel	24.0–28.0	0.20	24.0–28.0	0.20
Chromium	12.0–15.0	0.15	12.0–15.0	0.15
Molybdenum	2.0–3.5	0.10	1.25–2.25	0.10
Titanium	1.80–2.10	0.05	2.70–3.3	0.05
Aluminum	0.35 max	0.05 over	0.25 max	0.05 over
Copper	0.50 max	0.03 over	0.25 max	0.03 over
Boron	0.001–0.010	0.0004 under to 0.001 over	0.01–0.07	0.005

[A] Or columbium plus tantalum.

TABLE 4 Heat Treatment Requirements[A]

Grade	Class	Solution Treatment	Hardening Treatment
660	A	1650± 25 °F [900 ± 14 °C], hold 2 h, min, and liquid quench	1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool
	B	1800 ± 25 °F [980 ± 14 °C], hold 1 h, min, and liquid quench	1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool
	C	1800 ± 25 °F [980 ± 14 °C], hold 1 h min, and oil quench	1425 ± 25 °F [775 ± 14 °C] hold 16 h, air cool 1200 ± 25 °F [650 ± 14 °C] hold 16 h, air cool
	D	1650 ± 25 °F [900 ± 14 °C], hold 2 h min, and liquid quench or 1800 ± 25 °F [980 ± 14 °C], hold 1 h min, and liquid quench	1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool If necessary to achieve properties, second age: 1200 ± 25 °F [650 ± 14 °C] hold 16 h, air cool
651	A		hot-cold worked at 1200 °F [650 °C] min with 15 % min reduction in cross-sectional area, stress-relief anneal at 1200 °F [650 °C] min or 4 h, min
	B		hot-cold worked at 1200 °F [650 °C] min with 15 % min reduction of cross-sectional area, stress-relief anneal at 1350 °F [730 °C] min for 4 h, min
662	A	1800± 25 °F [980 ± 14 °C], hold 2 h, liquid quench	1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200± 25 °F [650 ± 14 °C], hold 20 h, air cool
	B	1950 ± 25 °F [1065 ± 14 °C], hold 2 h, liquid quench	1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200 ± 25 °F [650 ± 14 °C], hold 20 h, air cool
665	A	1800± 25 °F [980 ± 14 °C], hold 3 h, liquid quench	1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200± 25 °F [650 ± 14 °C], hold 20 h, air cool
	B	2000 ± 25 °F [1095 ± 14 °C], hold 3 h, liquid quench	1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200 ± 25 °F [650 ± 14 °C], hold 20 h, air cool

[A] Times refer to the minimum time material is required to be at temperature.

TABLE 5 Mechanical Property Requirements

Grade	Class	Tensile Strength, min		Yield Strength (0.2 % Offset), min		Elongation in 4× Diam, min, %	Reduction of Area, min, %	Brinell Hardness Number	Approximate Rockwell Hardness, B and C	
		ksi	MPa	ksi	MPa				min	max
660	A, B, and C	130	895	85	585	15	18	248–341	24 HRC	37 HRC
	D	130	895	105	725	15	18	248–321	24 HRC	35 HRC
651	A	100	690	70[A]	485	18	35	217–277	95 HRB	29 HRC
				60[B]	415					
	B	95	655	60[A]	415	18	35	212–269	93 HRB	28 HRC[C]
				50[B]	345					
662	A	130	895	85	585	15	18	248–321	24 HRC	35 HRC[C]
	B	125	860	80	550	15	18	248–321	24 HRC	35 HRC
665	A	170	1170	120	830	12	15	311–388	32 HRC	41 HRC
	B	155	1070	120	830	12	15	311–388	32 HRC	41 HRC

[A] Material sizes 3 in. [76 mm] and under in diameter.
[B] Material sizes over 3 in. [76 mm] in diameter.
[C] Conversion numbers taken from Specification A 193/A 193M, Table number 2 (austenitic steels); others by interpolation.

TABLE 6 Stress Rupture Requirements

Grade	Class	Test Temperature, °F [°C]	Stress, min		Time to Rupture, min, h[A]	Elongation, min, %
			ksi	MPa		
660	A, B, and C	1200 [650]	56	385	100	5
651	A and B	1200 [650]	40	275	100	5
662	A and B	1200 [650]	55	380	100	5
665	A	1200 [650]	75	515	100	3
	B	1200 [650]	70	485	100	5

[A] The combination bar specimen shown in Fig.number 1 shall be tested continuously at the temperature and at the minimum stress specified or at a greater stress and shall rupture in a time not less than that specified.

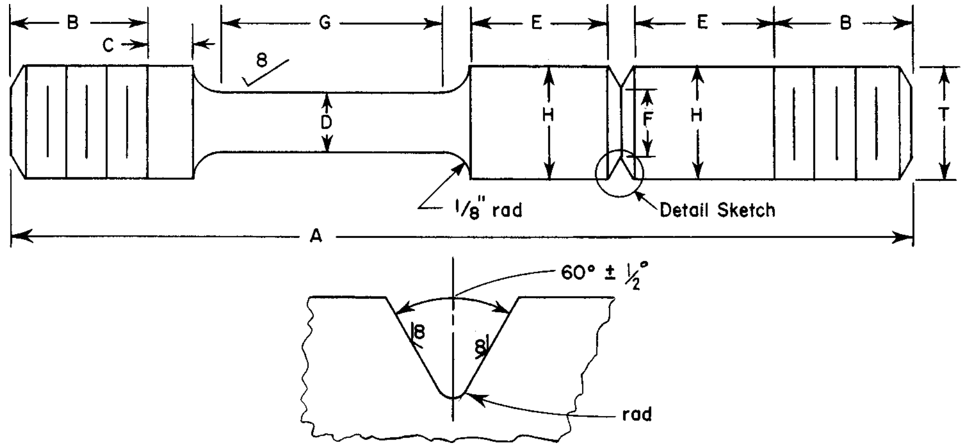


FIG. 1 Combination Smooth-Notch Stress-Rupture Test Specimen

(See Table 6)

8. Product Marking

8.1 *Bolts, Nuts, Screws, Studs, and Steel Bolts*—In addition to the grade and class shown in Table 4, the type designation (see 6.1.1) shall also appear on all bolting material so processed. Grade 660 Class D shall be stamped NR in addition to other required markings.

9. Keywords

9.1 bolts–steel; fasteners–steel; marking; nuts–steel; precipitation hardening steels; pressure vessel service; revision letter; steel bars–alloy; steel bolting material; steel flanges; steel values; temperature service applications–high; year date

TABLE 8 Permissible Variations in Size of Cold-Finished Bars

Specified Size, in. [mm]	Permissible Variations from Specified Size, in. [mm]^{A}	
	Over	Under
Over ½ to 1 [13 to 25], excl	0.002 [0.05]	0.002 [0.05]
1 to 1½ [25 to 38], excl	0.0025 [0.06]	0.0025 [0.06]
1½ to 4 [38 to 100], incl^{B}	0.003 [0.08]	0.003 [0.08]

^{A} When it is necessary to heat treat or heat treat and pickle after cold finishing, because of special hardness or mechanical property requirements, the permissible variations are generally double those shown in the table.

^{B} For size tolerances of sizes over 4 in. [100 mm], the manufacturer should be consulted.

TABLE 7 Test Specimen Dimensions

NOTE 1— Surfaces marked[8], finish to 8 µin. [0.2 µm] rms or better.

NOTE 2—The difference between dimensions *F* and *D* shall not exceed 0.0005 in. [0.01 mm] for specimens 1 or 2. The difference shall not exceed 0.001 in. [0.02 mm] for specimens 3, 4, 5, or 6.

NOTE 3—Taper the gage length *G* to the center so that the diameter *D* at the ends of the gage length exceeds the diameter at the center of the gage length by not less than 0.0005 in. [0.01 mm] nor more than 0.0015 in. [0.04 mm].

NOTE 4—All sections shall be concentric about the specimen axis within 0.001 in. [0.02 mm].

NOTE 5—Thread size *T* shall be equal to or greater than diameter *H*.

NOTE 6—Dimensions *A* and *B* are not specified.

NOTE 7—Length of shoulder *C*—⅛ + 1 ⁄ 32 −0 in. [3.2 + 0.8 mm].

NOTE 8—Length of shoulder *E*—⅜ + 1⁄32 −0 in. [10.0 + 0.8 mm].

Specimen Type	Mid-length Gage Dia *D* and Notch-Root Dia *F*	Gage Length, *G*	Shoulder Diameter, *H*	Notch-Root Radius
	Inches			
1	0.125	0.5	0.177	0.005
2	0.160	0.65	0.226	0.005
3	0.178	0.75	0.250	0.005
4	0.252	1.0	0.375	0.007
5	0.357	1.5	0.500	0.010
6	0.505	2.0	0.750	0.015
Tolerance	±0.001	±0.05	±0.003	±0.0005
	Millimetres			
7	3.17	12.0	4.5	0.13
8	4.06	17.0	5.5	0.13
9	4.52	20.0	6.5	0.13
10	6.40	25.0	9.5	0.18
11	9.07	40.0	12.0	0.25
12	12.8	50.0	19.0	0.38
Tolerance	±0.025	±1.3	±0.1	±0.01

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 453/A 453M – 03, that may impact the use of this specification. (Approved October 1, 2004)

(*1*) Added paragraph 7.3.2.3.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 453/A 453M – 02, that may impact the use of this specification. (Approved October 1, 2003)

(*1*) Revised 4.1.12, 7.2.1, 7.3.1, and 8.1 to include Grade 660 Class D.

(*2*) Corrected Hardness to Tensile conversions in Table 5.

Designation: A 451/A 451M – 06

Standard Specification for Centrifugally Cast Austenitic Steel Pipe for High-Temperature Service[1]

This standard is issued under the fixed designation A 451/A 451M; 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 austenitic alloy steel pipe for use in high-temperature, corrosive, or nuclear pressure service.

1.2 Several grades of austenitic stainless steel are covered as indicated in Table 1.

1.3 Optional supplementary requirements are provided when additional testing may be 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 exactly equivalents; therefore, each system must be used independently of each other. Combining values from the two systems may result in nonconformance with the specification.

NOTE 1—This specification is not intended to cover centrifugal pipe made from alloys containing more than 0.20 % carbon, such as are covered by Specification A 297.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 297/A 297M Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

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

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 94 Guide for Radiographic Examination

E 165 Test Method for Liquid Penetrant Examination

E 186 Reference Radiographs for Heavy-Walled (2 to 412-in. [51 to 114-mm]) Steel Castings

E 280 Reference Radiographs for Heavy-Walled (412 to 12-in. [114 to 305-mm]) Steel Castings

E 446 Reference Radiographs for Steel Castings Up to 2 in. [51 mm] in Thickness

2.2 *ANSI Standard:*

B46.1 Surface Texture[4]

3. Ordering Information

3.1 Orders for material to this specification shall 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 (centrifugally cast pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (outside or inside diameter and minimum wall thickness in inches or millimetres),

3.1.5 Length (specific or random, Specification A 999/A 999M),

3.1.6 End Finish of Specification A 999/A 999M,

3.1.7 Optional Requirements (9.4 and Supplementary Requirements S1 through S7),

3.1.8 Test Report Required (Section 14), and

3.1.9 Special Requirements or Additions to Specification.

4. Materials and Manufacture

4.1 *Heat-Treatment*—The pipe shall receive a heat-treatment at the temperature and time specified in Table 2, followed by a quench in water or rapid cool by other means.

4.2 *Machining*—The pipe shall be machined on the inner and outer surfaces to a roughness value no greater than 250-µin. [6.35-µm] arithmetical average deviation (AA) from the mean line, as defined in American National Standard B46.1.

5. Chemical Analysis

5.1 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of elements specified in Table 1. The analysis shall be made on a test sample taken preferably during the pouring of the heat. The

[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 A01.18 on Castings.

Current edition approved Sept. 1, 2006. Published September 2006. Originally approved in 1961. Last previous edition approved in 2002 as A 451/A 451M – 02.

[2] For ASME Boiler and Pressure Vessel Code applications see related specification SA-451 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 National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

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

TABLE 1 Chemical Requirements

Grade	Carbon, max	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Columbium	Tantalum, max	Nitrogen
	Composition, %										
CPF3	0.03	1.50	0.040	0.040	2.00	8.0–12.0	17.0–21.0	...	...	...	...
CPF3A	0.03	1.50	0.040	0.040	2.00	8.0–12.0	17.0–21.0	...	...	...	...
CPF8	0.08	1.50	0.040	0.040	2.00	8.0–11.0	18.0–21.0	...	...	...	...
CPF8A	0.08	1.50	0.040	0.040	2.00	8.0–11.0	18.0–21.0	...	...	...	...
CPF3M	0.03	1.50	0.040	0.040	1.50	9.0–13.0	17.0–21.0	2.0–3.0	...	...	...
CPF8M	0.08	1.50	0.040	0.040	1.50	9.0–12.0	18.0–21.0	2.0–3.0	...	...	...
CPF10MC[A]	0.10	1.50	0.040	0.040	1.50	13.0–16.0	15.0–18.0	1.75–2.25	1.2 max, 10 × C min	...	...
CPF8C[A]	0.08	1.50	0.040	0.040	2.00	9.0–12.0	18.0–21.0	...	1 max, 8 × C min	...	...
CPF8C(Ta max)[B]	0.08	1.50	0.040	0.040	2.00	9.0–12.0	18.0–21.0	...	1 max, 8 × C min	0.10	...
CPH8	0.08	1.50	0.040	0.040	1.50	12.0–15.0	22.0–26.0	...	...	...	...
CPH20 or CPH10	0.20[C]	1.50	0.040	0.040	2.00	12.0–15.0	22.0–26.0	...	...	...	...
CPK20	0.20	1.50	0.040	0.040	1.75	19.0–22.0	23.0–27.0	...	...	...	...
CPE20N	0.20	1.50	0.040	0.040	1.50	8.0–11.0	23.0–26.0	...	...	...	0.08–0.20

[A] Grades CPF10MC and CPF8C may have a columbium plus tantalum content maximum of 1.35 %.
[B] No designation as yet assigned by ASTM International or Steel Founders' Society of America.
[C] By agreement between the manufacturer and the purchaser, the carbon content of Grade CPH20 may be restricted to 0.10 % max. When so agreed, the grade designation shall be CPH10.

TABLE 2 Heat-Treatment Requirements

Grade	Temperature, min °F	Temperature, min °C	Hold Time, h/in. of Thickness
CPF3, CPF3A, CPF8, CPF8A, CPF3M, CPF8M	1900	1040	1
CPF10MC, CPF8C, CPF8C (Ta max)	1950	1065	2
CPH8, CPH10, CPH20, CPK20	2100	1150	1
CPE20N	2225	1220	1

chemical composition thus determined shall conform to the requirements specified in Table 1.

5.2 *Product Analysis*—A product analysis may be made by the purchaser. The sample for analysis shall be selected so as to be thoroughly representative of the pipe being analyzed. The chemical composition thus determined shall conform to the requirements specified in Table 1.

5.3 To determine conformance with the chemical analysis requirements, an observed value or calculated value shall be rounded in accordance with Practice E 29 to the nearest unit in the last right-hand place of values listed in Table 1.

6. Tensile Requirements

6.1 *Test Specimens*:

6.1.1 Test specimens shall be prepared in accordance with Test Methods and Definitions A 370. Test bars shall be poured in special blocks from the same heat as the castings represented. Test bars shall be supplied in sufficient number to furnish all specimens required in 6.2 and 6.3 (see Table 3).

6.1.2 Test specimens may be cut from heat-treated castings instead of from test bars when agreed upon between the manufacturer and the purchaser.

6.1.3 Tension test specimens shall be machined to the form and dimensions of the standard round 2-in. [50-mm] gage length specimens shown in Fig. 6 of Test Methods and Definitions A 370.

6.2 *Number of Tests*:

TABLE 3 Tensile Requirements

Grade	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min
CPF3	70 [485]	30 [205]	35
CPF3A[A]	77 [535]	35 [240]	35
CPF3M	70 [485]	30 [205]	30
CPF8	70 [485]	30 [205]	35
CPF8A[A]	77 [535]	35 [240]	35
CPF8M	70 [485]	30 [205]	30
CPF10MC	70 [485]	30 [205]	20
CPH10	70 [485]	30 [205]	30
CPF8C (Ta max), CPF8C	70 [485]	30 [205]	30
CPH8	65 [448]	28 [195]	30
CPK20	65 [448]	28 [195]	30
CPH20	70 [485]	30 [205]	30
CPE20N	80 [550]	40 [275]	30

[A] The properties shown are obtained by adjusting the composition within the limits shown in Table 1 to obtain a ferrite-austenite ratio that will result in the higher ultimate and yield strengths indicated. A lowering of impact values may develop in these materials when exposed to service temperature above 800°F [425°C].

6.2.1 One tension test shall be made from each heat. The bar from which the test specimen is taken shall be heat-treated in the same manner as the castings represented.

6.2.2 If a specimen is machined improperly or flaws are revealed by machining or during testing, the specimen may be discarded and another substituted from the same heat.

6.3 *Retests*—If the results of the mechanical tests for any heat do not conform to the requirements specified, the castings may be reheat-treated and retested, but may not be solution-treated more than twice.

7. Hydrostatic Test

7.1 Each length of pipe shall be hydrostatically tested in accordance with Specification A 999/A 999M.

7.2 It is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work has been performed on the casting. In such cases, the foundry is responsible for the satisfactory performance of the casting when it is tested.

8. Quality

8.1 The surface of the casting shall be examined visually and shall be free from cracks and hot tears. Other surface defects shall be judged in accordance with visual acceptance criteria which may be specified in the order.

9. Rework and Retreatment

9.1 Defects as defined in Section 8 shall be removed and their removal verified by visual inspection of the resultant cavities. Defects which are located by inspecting with Supplementary Requirement S6 or S7, or both, shall be removed or reduced to an acceptable size.

9.2 If removal of the defect does not infringe upon the minimum wall thickness, the depression may be blended uniformly into the surrounding surface.

9.3 If the cavity resulting from defect removal infringes upon the minimum wall thickness, weld repair is permitted subject to the purchasers' approval. The composition of the weld rod used shall be suitable for the composition of the metal being welded.

9.3.1 Only operators and procedures qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX, shall be used. All repair welds will be inspected to the same quality standards used to inspect the casting.

9.4 Postweld heat-treatment of the repaired casting is neither required nor prohibited.

10. Permissible Variations in Dimensions

10.1 *Thickness*—The wall thickness shall not vary over that specified by more than ⅛ in. (3 mm). There shall be no variation under the specified wall thickness.

11. General Requirements

11.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M, unless otherwise provided herein.

12. Rejection

12.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the pipe may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

13. Rehearing

13.1 Samples that represent rejected material shall be preserved for 2 weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

14. Certification

14.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

15. Product Marking

15.1 Each length of pipe shall be legibly marked with the manufacturer's name or brand, the letters ASTM, the specification number, and grade. In addition, heat numbers, or serial numbers that are traceable to heat numbers, shall be marked on each length of pipe.

16. Keywords

16.1 austenitic; centrifugally cast; height; high-temperature service; stainless steel; steel castings

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Additional Tension Tests

S1.1 Additional tension tests shall be made at a temperature to be specified by the customer, and the properties to be met are a matter of agreement between purchaser and manufacturer.

S2. Flattening Test

S2.1 The flattening test shall be made on specimens from one or both ends of each length of pipe. If the specimen from any end of any length fails to conform to the requirements of Specification A 999/A 999M, that length shall be rejected.

S3. Photomicrographs

S3.1 The manufacturer shall furnish one photomicrograph at 100 diameters from one specimen of as-finished pipe from each heat in each heat-treatment lot. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, and heat. Such photomicrographs are for information only, to show the actual metal structure of the pipe as furnished. No photomicrographs for the individual pieces purchased shall be required except as specified in Supplementary Requirement S4.

S4. Photomicrographs for Individual Pieces

S4.1 The manufacturer shall furnish photomicrographs from one or both ends of each pipe. All photomicrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S5. Metal Structure and Etching Tests

S5.1 Etching tests (Note S1) shall be made on transverse sections from the pipe and shall reveal the macrostructure of the material. Such tests are for information only.

NOTE S1—Pending development of etching methods applicable to the product covered by this specification, it is recommended that the Recommended Practice for a Standard Macroetch Test for Routine Inspection of Iron and Steel be followed.[5]

[5] *Metals Handbook*, American Society for Metals, Vol 8, 8th ed., 1973, pp. 70-77.

S6. Radiographic Examination

S6.1 The castings shall be examined for internal defects by means of X rays or gamma rays. The inspection procedure shall be in accordance with Guide E 94 and the types and degrees of discontinuities considered shall be judged by Reference Radiographs E 446, E 186, or E 280. The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser.

S7. Liquid Penetrant Examination

S7.1 The castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The method of performing the liquid penetrant test shall be in accordance with Test Method E 165. The areas to be inspected, the methods and types of liquid penetrants to be used, the developing procedure, and the basis for acceptance shall be as specified on the inquiry or invitation to bid and on the purchase order or contract or both, or as agreed upon between the manufacturer and the purchaser.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 451/A 451M (2002)) that may impact the use of this standard (Approved Sept. 1, 2006).

(1) Replaced reference to A 530/A 530M with reference to A 999/A 999M in Section 2.

(2) In sections 3.1.5, 3.1.6, 7.1, and 11.1, replaced reference to A 530/A 530M with reference to A 999/A 999M.

Designation: A 450/A 450M – 04a

Standard Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes[1]

This standard is issued under the fixed designation A 450/A 450M; 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*

1.1 This specification[2] covers a group of requirements which, with the exceptions of 5.3 and Sections 6, 7, 18, 19, 20, 21, 22, 23, and 24, are mandatory requirements to the following ASTM tubular product specifications:[3]

Title of Specification	ASTM Designation[A]
Electric-Resistance-Welded Carbon Steel and Carbon Manganese Steel Boiler Tubes	A 178/A 178M
Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes	A 179/A 179M
Seamless Carbon Steel Boiler Tubes for High-Pressure Service	A 192/A 192M
Seamless Medium-Carbon Steel Boiler and Superheater Tubes	A 210/A 210M
Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes	A 214/A 214M
Seamless and Electric-Welded Low-Alloy Steel Tubes	A 423/A 423M
Electric-Resistance-Welded Coiled Steel Tubing for Gas and Fuel Oil Lines	A 539
Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes	A 556/A 556M
Seamless, Cold-Drawn Carbon Steel Tubing for Hydraulic System Service	A 822

[A] These designations refer to the latest issue of the respective specifications.

1.2 One or more of Sections 5.3, 6, 7, 18, 19, 20, 21, 21.1, 23, and 24 apply when the product specification or purchase order has a requirement for the test or analysis described by these sections.

1.3 In case of conflict between a requirement of the product specification and a requirement of this general requirement specification only the requirement of the product specification need be satisfied.

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 (SI) of the product specification is specified in the order.

2. Referenced Documents

2.1 *ASTM Standards:* [4]

A 178/A 178M Specification for Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes
A 179/A 179M Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes
A 192/A 192M Specification for Seamless Carbon Steel Boiler Tubes for High-Pressure Service
A 210/A 210M Specification for Seamless Medium-Carbon Steel Boiler and Superheater Tubes
A 214/A 214M Specification for Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 423/A 423M Specification for Seamless and Electric-Welded Low-Alloy Steel Tubes
A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe
A 539 Specification for Electric-Resistance-Welded Coiled Steel Tubing for Gas and Fuel Oil Lines[5]
A 556/A 556M Specification for Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes
A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 822 Specification for Seamless Cold-Drawn Carbon Steel

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Oct. 1, 2004. Published October 2004. Originally approved in 1961. Last previous edition approved in 2004 as A 450/A 450M – 04.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-450 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vols 01.01 and 01.04.

[4] 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.

[5] Withdrawn.

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

Tubing for Hydraulic System Service

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

D 3951 Practice for Commercial Packaging

E 92 Test Method for Vickers Hardness of Metallic Materials

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing

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

E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel, and Similar Alloys

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

2.2 *Federal Standard:*

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products[6]

2.3 *Military Standards:*

MIL-STD-271 Nondestructive Testing Requirements for Metals[6]

MIL-STD-792 Identification Marking Requirements for Special Purpose Equipment[6]

2.4 *ASME Boiler and Pressure Vessel Code:*

Section IX Welding Qualifications[7]

2.5 *Steel Structures Painting Council:*

SSPC-SP 6 Surface Preparation Specification No. 6 Commercial Blast Cleaning[8]

2.6 *Other Document:*

SNT-TC-1A Recommended Practice for Nondestructive Personnel Qualification and Certification.

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *remelted heat*—in secondary melting, all of the ingots remelted from a single primary heat.

3.1.2 *thin-wall tube*—a tube meeting the specified outside diameter and specified wall thickness set forth as follows:

Specified Outside Diameter	Specified Wall Thickness
2 in. [50.8 mm] or less	2 % or less of specified outside diameter
Greater than 2 in. [50.8 mm]	3 % or less of specified outside diameter
Any	0.020 in. [0.5 mm] or less

3.2 *Other defined terms*—The definitions in Test Methods and Definitions A 370, Test Methods, Practices, and Terminology A 751, and Terminology A 941 are applicable to this specification and to those listed in 1.1.

4. Process

4.1 The steel may be made by any process.

4.2 If a specific type of melting is required by the purchaser, it shall be as stated on the purchase order.

4.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, such as electroslag remelting or vacuum-arc remelting.

4.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

5. Chemical Composition

5.1 Samples for chemical analysis, and method of analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

5.2 *Heat Analysis*—If the heat analysis reported by the steel producer is not sufficiently complete for conformance with the heat analysis requirements of the applicable product specification to be fully assessed, the manufacturer may complete the assessment of conformance with such heat analysis requirements by using a product analysis for the specified elements that were not reported by the steel producer, provided that product analysis tolerances are not applied and the heat analysis is not altered.

5.3 *Product Analysis*—Product analysis requirements and options, if any, are contained in the product specification.

6. Tensile Properties

6.1 The material shall conform to the requirements as to tensile properties prescribed in the individual specification.

6.2 The yield strength corresponding to a permanent offset of 0.2 % of the gage length or to a total extension of 0.5 % of the gage length under load shall be determined.

6.3 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than ¾ in. [19.0 mm] from the center of the gage length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

[6] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.

[7] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

[8] Available from Steel Structures Painting Council (SSPC), 40 24th St., 6th Floor, Pittsburgh, PA 15222-4656.

7. Standard Weights

7.1 The calculated weight per foot, based upon a specified minimum wall thickness, shall be determined by the following equation:

$$W = C(D - t)t \quad (1)$$

where:
C = 10.69 [0.0246615],
W = weight, lb/ft [kg/m],
D = specified outside diameter, in. [mm], and
t = specified minimum wall thickness, in. [mm]

7.2 The permissible variations from the calculated weight per foot [kilogram per metre] shall be as prescribed in Table 1.

8. Permissible Variations in Wall Thickness

8.1 Variations from the specified minimum wall thickness shall not exceed the amounts prescribed in Table 2.

8.2 For tubes 2 in. [50.8 mm] and over in outside diameter and 0.220 in. [5.6 mm] and over in thickness, the variation in wall thickness in any one cross section of any one tube shall not exceed the following percentage of the actual mean wall at the section. The actual mean wall is defined as the average of the thickest and thinnest wall in that section.

Seamless tubes ±10 %
Welded tubes ±5 %

8.3 When cold-finished tubes as ordered require wall thicknesses ¾ in. [19.1 mm] or over, or an inside diameter 60 % or less of the outside diameter, the permissible variations in wall thickness for hot-finished tubes shall apply.

9. Permissible Variations in Outside Diameter

9.1 Except as provided in 9.2 and 9.3, variations from the specified outside diameter shall not exceed the amounts prescribed in Table 3.

9.2 Thin-wall tubes usually develop significant ovality (out of roundness) during final annealing, or straightening, or both. The diameter tolerances of Table 3 are not sufficient to provide for additional ovality expected in thin-wall tubes, and, for such tubes, are applicable only to the *mean* of the extreme (maximum and minimum) outside diameter readings in any one cross section. However, for thin wall tubes the *difference* in extreme outside diameter readings (ovality) in any one cross section shall not exceed the following ovality allowances:

Outside Diameter	Ovality Allowance
1 in. [25.4 mm] and under	0.020 in. [0.5 mm]
Over 1 in. [25.4 mm]	2.0 % of specified outside diameter

TABLE 1 Permissible Variations in Weight Per Foot[A]

Method of Manufacture	Permissible Variation in Weight per Foot, %	
	Over	Under
Seamless, hot-finished	16	0
Seamless, cold-finished:		
1½ in. [38.1 mm] and under OD	12	0
Over 1½ in. [38.1 mm] OD	13	0
Welded	10	0

[A] These permissible variations in weight apply to lots of 50 tubes or more in sizes 4 in. [101.6 mm] and under in outside diameter, and to lots of 20 tubes or more in sizes over 4 in. [101.6 mm] in outside diameter.

TABLE 2 Permissible Variations in Wall Thickness[A]

Outside Diameter, in. [mm]	Wall Thickness, %: 0.095 [2.4] and Under		Over 0.095 to 0.150 [2.4 to 3.8], incl		Over 0.150 to 0.180 [3.8 to 4.6], incl		Over 0.180, [4.6]	
	Over	Under	Over	Under	Over	Under	Over	Under
Seamless, Hot-Finished Tubes								
4 [101.6] and under	40	0	35	0	33	0	28	0
Over 4 [101.6]	...	...	35	0	33	0	28	0
Seamless, Cold-Finished Tubes								
	Over				Under			
1½ [38.1] and under	20				0			
Over 1½ [38.1]	22				0			
Welded Tubes								
All sizes	18				0			

[A] These permissible variations in wall thickness apply only to tubes, except internal-upset tubes, as rolled or cold-finished, and before swaging, expanding, bending, polishing, or other fabricating operations.

TABLE 3 Permissible Variations in Outside Diameter[A]

Outside Diameter, in. [mm]	Permissible Variations, in. [mm]: Over	Under
Hot-Finished Seamless Tubes		
4 [101.6] and under	1⁄64 [0.4]	1⁄32 [0.8]
Over 4 to 7½ [101.6 to 190.5], incl	1⁄64 [0.4]	3⁄64 [1.2]
Over 7½ to 9 [190.5 to 228.6], incl	1⁄64 [0.4]	1⁄16 [1.6]
Welded Tubes and Cold-Finished Seamless Tubes		
Under 1 [25.4]	0.004 [0.1]	0.004 [0.1]
1 to 1½ [25.4 to 38.1], incl	0.006 [0.15]	0.006 [0.15]
Over 1½ to 2 [38.1 to 50.8], excl	0.008 [0.2]	0.008 [0.2]
2 to 2½ [50.8 to 63.5], excl	0.010 [0.25]	0.010 [0.25]
2½ to 3 [63.5 to 76.2], excl	0.012 [0.3]	0.012 [0.3]
3 to 4 [76.2 to 101.6], incl	0.015 [0.38]	0.015 [0.38]
Over 4 to 7½ [101.6 to 190.5], incl	0.015 [0.38]	0.025 [0.64]
Over 7½ to 9 [190.5 to 228.6], incl	0.015 [0.38]	0.045 [1.14]

[A] Except as provided in 9.2 and 9.3, these permissible variations include out-of-roundness. These permissible variations in outside diameter apply to hot-finished seamless, welded and cold-finished seamless tubes before other fabricating operations such as upsetting, swaging, expanding, bending, or polishing.

9.3 For cold-finished seamless austenitic and ferritic/austenitic tubes an ovality allowance is necessary for all sizes less than 2 in. [50.8 mm] outside diameter since they are likely to become out of round during their final heat treatment. In such tubes, the maximum and minimum diameters at any cross section shall deviate from the nominal diameter by no more than ±0.010 in. [±0.25 mm]; however, the mean diameter at that cross section must still be within the given permissible variation given in Table 3. In the event of conflict between the provisions of 9.3 and those of 9.2, the larger value of ovality tolerance shall apply.

10. Permissible Variations in Length

10.1 Variations from the specified length shall not exceed the amounts prescribed in Table 4.

TABLE 4 Permissible Variations in Length[A]

Method of Manufacture	Outside Diameter, in. [mm]	Cut Length, in. [mm]	
		Over	Under
Seamless, hot-finished	All sizes	3⁄16 [5]	0 [0]
Seamless, cold-finished	Under 2 [50.8]	1⁄8 [3]	0 [0]
	2 [50.8] and over	3⁄16 [5]	0 [0]
Welded	Under 2 [50.8]	1⁄8 [3]	0 [0]
	2 [50.8] and over	3⁄16 [5]	0 [0]

[A] These permissible variations in length apply to tubes before bending. They apply to cut lengths up to and including 24 ft [7.3 m]. For lengths greater than 24 ft [7.3 m], the above over-tolerances shall be increased by 1⁄8 in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft or 1⁄2 in. [13 mm], whichever is the lesser.

11. Permissible Variations in Height of Flash on Electric-Resistance-Welded Tubes

11.1 For tubes over 2 in. [50.8 mm] in outside diameter, or over 0.135 in. [3.44 mm] in wall thickness, the flash on the inside of the tubes shall be mechanically removed by cutting to a maximum height of 0.010 in. [0.25 mm] at any point on the tube.

11.2 For tubes 2 in. [50.8 mm] and under in outside diameter and 0.135 in. [3.4 mm] and under in wall thickness, the flash on the inside of the tube shall be mechanically removed by cutting to a maximum height of 0.006 in. [0.15 mm] at any point on the tube.

12. Straightness and Finish

12.1 Finished tubes shall be reasonably straight and have smooth ends free of burrs. They shall have a workmanlike finish. Surface imperfections (see Note 1) may be removed by grinding, provided that a smooth curved surface is maintained, and the wall thickness is not decreased to less than that permitted by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed.

NOTE 1—An imperfection is any discontinuity or irregularity found in the tube.

13. Repair by Welding

13.1 Repair welding of base metal defects in tubing is permissible only with the approval of the purchaser and with the further understanding that the tube shall be marked "WR" and the composition of the deposited filler metal shall be suitable for the composition being welded. Defects shall be thoroughly chipped or ground out before welding and each repaired length shall be reheat treated or stress relieved as required by the applicable specification. Each length of repaired tube shall be tested hydrostatically as required by the product specification.

13.2 Repair welding shall be performed using procedures and welders or welding operators that have been qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

14. Retests

14.1 If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional tubes of double the original number from the same group or lot, each of which shall conform to the requirements specified.

15. Retreatment

15.1 If the individual tubes or the tubes selected to represent any group or lot fail to conform to the test requirements, the individual tubes or the group or lot represented may be retreated and resubmitted for test. Not more than two reheat treatments shall be permitted.

16. Test Specimens

16.1 Test specimens shall be taken from the ends of finished tubes prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free of burrs and flaws.

16.2 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

17. Method of Mechanical Testing

17.1 The specimens and mechanical tests required shall be made in accordance with Annex A2 of Test Methods and Definitions A 370.

17.2 Specimens shall be tested at room temperature.

17.3 Small or subsize specimens as described in Test Methods and Definitions A 370 may be used only when there is insufficient material to prepare one of the standard specimens. When using small or subsize specimens, the largest one possible shall be used.

18. Flattening Test

18.1 A section of tube not less than 2 ½ in. [63 mm] in length for seamless and not less than 4 in. [100 mm] in length for welded shall be flattened cold between parallel plates in two steps. For welded tubes, the weld shall be placed 90° from the direction of the applied force (at a point of maximum bending). During the first step, which is a test for ductility, no cracks or breaks, except as provided for in 18.4, on the inside, outside, or end surfaces shall occur in seamless tubes, or on the inside or outside surfaces of welded tubes, until the distance between the plates is less than the value of H calculated by the following equation:

$$H = \frac{(1 + e)t}{e + t/D} \tag{2}$$

where:

H = distance between flattening plates, in. [mm],
t = specified wall thickness of the tube, in. [mm],
D = specified outside diameter of the tube, in. [mm], and
e = deformation per unit length (constant for a given grade of steel: 0.07 for medium-carbon steel (maximum specified carbon 0.19 % or greater), 0.08 for ferritic alloy steel, 0.09 for austenitic steel, and 0.09 for low-carbon steel (maximum specified carbon 0.18 % or less)).

During the second step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the tube meet. Evidence of laminated or unsound material, or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

18.2 Surface imperfections in the test specimens before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements.

18.3 Superficial ruptures resulting from surface imperfections shall not be cause for rejection.

18.4 When low *D*-to- *t* ratio tubular products are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the *D* to *t* ratio is less than 10.

19. Reverse Flattening Test

19.1 A 5 in. [100 mm] in length of finished welded tubing in sizes down to and including ½ in. [12.7 mm] in outside diameter shall be split longitudinally 90° on each side of the weld and the sample opened and flattened with the weld at the point of maximum bend. There shall be no evidence of cracks or lack of penetration or overlaps resulting from flash removal in the weld.

20. Flaring Test

20.1 A section of tube approximately 4 in. [100 mm] in length shall stand being flared with a tool having a 60° included angle until the tube at the mouth of the flare has been expanded to the percentages specified in Table 5 without cracking or showing imperfections rejectable under the provisions of the product specification.

21. Flange Test

21.1 A section of tube shall be capable of having a flange turned over at a right angle to the body of the tube without cracking or showing imperfections rejectable under the provisions of the product specification. The width of the flange for carbon and alloy steels shall be not less than the percentages specified in Table 6. For the austenitic grades, the width of the flange for all sizes listed in Table 6 shall be not less than 15 %.

22. Hardness Test

22.1 For tubes 0.200 in. [5.1 mm] and over in wall thickness, either the Brinell or Rockwell hardness test shall be used.

TABLE 5 Flaring Test Requirements

Ratio of Inside Diameter to Outside Diameter[A]	Minimum Expansion of Inside Diameter, %	
	Carbon, Carbon-Molybdenum, and Austenitic Steels	Other Ferritic Alloy Steels
0.9	21	15
0.8	22	17
0.7	25	19
0.6	30	23
0.5	39	28
0.4	51	38
0.3	68	50

[A] In determining the ratio of inside diameter to specified outside diameter, the inside diameter shall be defined as the actual mean inside diameter of the material tested.

TABLE 6 Flange Requirements

Outside Diameter of Tube, in. [mm]	Width of Flange
To 2½ [63.5], incl	15 % of OD
Over 2½ to 3¾ [63.5 to 95.2], incl	12½ % of OD
Over 3¾ to 8 [95.2 to 203.2], incl	10 % of OD

When Brinell hardness testing is used, a 10-mm ball with 3000, 1500, or 500-kg load, or a 5-mm ball with 750-kg load may be used, at the option of the manufacturer.

22.2 For tubes less than 0.200 in. [5.1 mm] to and including 0.065 in. [1.7 mm] in wall thickness, the Rockwell hardness test shall be used.

22.3 For tubes less than 0.065 in. [1.7 mm] in wall thickness, the hardness test shall not be required.

22.4 The Brinell hardness test may be made on the outside of the tube near the end, on the outside of a specimen cut from the tube, or on the wall cross section of a specimen cut from the tube at the option of the manufacturer. This test shall be made so that the distance from the center of the impression to the edge of the specimen is at least 2.5 times the diameter of the impression.

22.5 The Rockwell hardness test may be made on the inside surface, on the wall cross section, or on a flat on the outside surface at the option of the manufacturer.

22.6 For tubes furnished with upset, swaged, or otherwise formed ends, the hardness test shall be made as prescribed in 22.1 and 22.2 on the outside of the tube near the end after the forming operation and heat treatment.

22.7 For welded or brazed tubes, the hardness test shall be made away from the joints.

22.8 When the product specification provides for Vickers hardness, such testing shall be in accordance with Test Method E 92.

23. Hydrostatic Test

23.1 Except as provided in 23.2 and 23.3, each tube shall be tested by the manufacturer to a minimum hydrostatic test pressure determined by the following equation:

$$\begin{aligned} &\text{Inch-Pound Units: } P = 32000\, t/D \\ &\text{SI Units: } P = 220.6t/D \end{aligned} \quad (3)$$

where:
P = hydrostatic test pressure, psi or MPa,
t = specified wall thickness, in. or mm, and
D = specified outside diameter, in. or mm.

23.1.1 The hydrostatic test pressure determined by Eq 3 shall be rounded to the nearest 50 psi [0.5 MPa] for pressure below 1000 psi [7 MPa], and to the nearest 100 psi [1 MPa] for pressures 1000 psi [7 MPa] and above. The hydrostatic test may be performed prior to cutting to final length, or prior to upsetting, swaging, expanding, bending or other forming operations, or both.

23.2 Regardless of the determination made by Eq 3, the minimum hydrostatic test pressure required to satisfy these requirements need not exceed the values given in Table 7. This does not prohibit testing at higher pressures at manufacturer's option or as provided in 23.3.

TABLE 7 Hydrostatic Test Pressures

Outside Diameter of Tube, in. [mm]	Hydrostatic Test Pressure, psi [MPa]
Under 1 [25.4]	1000 [7]
1 to 1½ [25.4 to 38.1], excl	1500 [10]
1½ to 2 [38.1 to 50.8], excl	2000 [14]
2 to 3 [50.8 to 76.2], excl	2500 [17]
3 to 5 [76.2 to 127], excl	3500 [24]
5 [127] and over	4500 [31]

23.3 With concurrence of the manufacturer, a minimum hydrostatic test pressure in excess of the requirements of 23.2 or 23.1, or both, may be stated on the order. The tube wall stress shall be determined by the following equation:

$$S = PD/2t \tag{4}$$

where:

S = tube wall stress, psi or MPa, and all other symbols as defined in 23.1.1.

23.4 The test pressure shall be held for a minimum of 5 s.

23.5 If any tube shows leaks during the hydrostatic test, it shall be rejected.

23.6 The hydrostatic test may not be capable of testing the end portion of the pipe. The lengths of pipe that cannot be tested shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

24. Air Underwater Pressure Test

24.1 When this test is employed, each tube, with internal surface clean and dry, shall be internally pressurized to 150 psi [1000 kPa] minimum with clean and dry compressed air while being submerged in clear water. The tube shall be well-lighted, preferably by underwater illumination. Any evidence of air leakage of the pneumatic couplings shall be corrected prior to testing. Inspection shall be made of the entire external surface of the tube after holding the pressure for not less than 5 s after the surface of the water has become calm. If any tube shows leakage during the air underwater test, it shall be rejected. Any leaking areas may be cut out and the tube retested.

25. Nondestructive Examination

25.1 When nondestructive examination is specified by the purchaser or the product specification, each tube shall be examined by a nondestructive examination method in accordance with Practice E 213, Practice E 309 (for ferromagnetic materials), Practice E 426 (for non-magnetic materials), or Practice E 570. Upon agreement, Practice E 273 shall be employed in addition to one of the full periphery tests. The range of tube sizes that may be examined by each method shall be subject to the limitations in the scope of that practice. In case of conflict between these methods and practices and this specification, the requirements of this specification shall prevail.

25.2 The following information is for the benefit of the user of this specification.

25.2.1 Calibration standards for the nondestructive electric test are convenient standards for calibration of nondestructive testing equipment only. For several reasons, including shape, orientation, width, etc., the correlation between the signal produced in the electric test from an imperfection and from calibration standards is only approximate. A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

25.2.2 The ultrasonic examination referred to in this specification is intended to detect longitudinal discontinuities having a reflective area similar to or larger than the calibration reference notches specified in 25.4. The examination may not detect circumferentially oriented imperfections or short, deep defects.

25.2.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type. Practices E 309 and E 426 contain additional information regarding the capabilities and limitations of eddy-current examination.

25.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. The provisions of this specification only provide for longitudinal calibration for flux leakage. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

25.2.5 The hydrostatic test referred to in Section 22 is a test method provided for in many product specifications. This test has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall defects or defects that extend an appreciable distance into the wall without complete penetration.

25.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular products.

25.3 *Time of Examination*—Nondestructive examination for specification acceptance shall be performed after all deformation processing, heat treating, welding, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

25.4 *Surface Condition*:

25.4.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

25.4.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

25.5 *Extent of Examination*:

25.5.1 The relative motion of the tube and the transducer(s), coil(s), or sensor(s) shall be such that the entire tube surface is scanned, except for end effects as noted in 25.5.2.

25.5.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

25.6 *Operator Qualifications*:

25.6.1 The test unit operator shall be certified in accordance with SNT TC-1-A, or an equivalent documented standard agreeable to both purchaser and manufacturer.

25.7 *Test Conditions*:

25.7.1 For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.0 MHz, and the maximum transducer size shall be 1.5 in. (38 mm).

25.7.2 For eddy current testing, the excitation coil frequency shall be chosen to ensure adequate penetration, yet provide good signal-to-noise ratio.

25.7.2.1 The maximum coil frequency shall be:

Specified Wall Thickness	Maximum Frequency
<0.050 in.	100 KHz
0.050 to 0.150	50
>0.150	10

25.8 *Reference Standards*:

25.8.1 Reference standards of convenient length shall be prepared from a length of tube of the same grade, specified size (outside diameter and wall thickness), surface finish and heat treatment condition as the tubing to be examined.

25.8.2 *For eddy current testing*, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

25.8.2.1 *Drilled Hole*—The reference standard shall contain three or more holes, equally spaced circumferentially around the tube and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the tube wall, with care being taken to avoid distortion of the tube while drilling. The holes shall not be larger than 0.031 in. (0.8 mm) in diameter. As an alternative, the producer may choose to drill one hole and run the calibration standard through the test coil three times, rotating the tube approximately 120° each time. More passes with smaller angular increments may be used, provided testing of the full 360° of the coil is obtained. For welded tubing, if the weld is visible, one of the multiple holes or the single hole shall be drilled in the weld.

25.8.2.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼ in. (6.4 mm) diameter, a notch shall be milled or filed tangential to the surface and transverse to the longitudinal axis of the tube. Said notch shall have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. (0.1 mm), whichever is greater.

25.8.2.3 *Longitudinal Notch*—A notch 0.031 in. (0.8 mm) or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. (0.1 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

25.8.3 *For ultrasonic testing*, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of the notches shall not exceed 12½ % of the specified wall thickness of the tube or 0.004 in. (0.1 mm), whichever is greater. The width of the notch shall not exceed two times the depth. For welded tubing, the notches shall be placed in the weld, if the weld is visible.

25.8.4 *For flux leakage testing*, the longitudinal reference notches shall be straight-sided notches machined in a radial plane parallel to the tube axis on the inside and outside surfaces of the tube. Notch depth shall not exceed 12½ % of the specified wall thickness or 0.004 in. (0.1 mm), whichever is greater. Notch length shall not exceed 1 in. (25.4 mm), and the width shall not exceed the depth. Outside and inside notches shall have sufficient separation to allow distinct identification of the signal from each notch.

25.8.5 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

25.9 *Standardization Procedure*:

25.9.1 The test apparatus shall be standardized at the beginning and end of each series of tubes of the same specified size (diameter and wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h during the examination of such tubing. More frequent standardizations may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

25.9.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss or shutdown.

25.9.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the tube to be tested, except that, at the manufacturer's discretion, the tubes may be tested at a higher sensitivity.

25.9.4 The signal-to-noise ratio for the reference standard shall be 2.5:1 or greater, and the reference signal amplitude for each discontinuity shall be at least 50 % of full scale of the display. In establishing the noise level, extraneous signals from identifiable surface imperfections on the reference standard may be ignored. When reject filtering is used during UT testing, linearity must be demonstrated.

25.9.5 If, upon any standardization, the reference signal amplitude has decreased by 29 % (3.0 dB), the test apparatus shall be considered out of standardization. The test system settings may be changed, or the transducer(s), coil(s), or sensor(s) adjusted, and the unit restandardized, but all tubes tested since the last acceptable standardization must be retested.

25.10 *Evaluation of Imperfections*:

25.10.1 Tubing producing a test signal to or greater than the lowest signal produced by the reference standard shall be designated suspect, shall be clearly marked or identified, and shall be separated from the acceptable tubing.

25.10.2 Such suspect tubing shall be subject to one of the following three dispositions:

25.10.2.1 The tubes may be rejected without further examination, at the discretion of the manufacturer.

25.10.2.2 If the test signal was produced by imperfections such as scratches, surface roughness, dings, straightener marks, loose ID bead and cutting chips, steel die stamps, stop marks, tube reducer ripple, or chattered flash trim, the tubing may be accepted or rejected depending on visual observation of the severity of the imperfection, the type of signal it produces on the testing equipment used, or both.

25.10.2.3 If the test signal was produced by imperfections which cannot be identified, or was produced by cracks or crack-like imperfections, the tubing shall be rejected.

25.10.3 Any tubes with imperfections of the types in 25.10.2.2 and 25.10.2.3, exceeding 0.004 in. (0.1 mm) or 12½ % of the specified minimum wall thickness (whichever is greater) in depth shall be rejected.

25.10.4 Rejected tubes may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. If grinding is performed, the outside diameter in the area of grinding may be reduced by the amount so removed. To be accepted, reconditioned tubes must pass the nondestructive examination by which they were originally rejected.

26. Certified Test Report

26.1 When specified in the purchase order or contract, the producer or supplier shall furnish a certified test report certifying that the material was manufactured, sampled, tested and inspected in accordance with the specification, including year date, the supplementary requirements, and any other requirements designated in the purchase order or contract, and that the results met the requirements of that specification, the supplementary requirements and the other requirements. A signature or notarization is not required on the certified test report, but the document shall be dated and shall clearly identify the organization submitting the report.

NOTE 2—Notwithstanding the absence of a signature or notarization, the organization submitting the report is responsible for the contents of the report.

26.2 In addition, the certified test report shall include the following information and test results, when applicable:

26.2.1 Heat Number,

26.2.2 Heat Analysis,

26.2.3 Product Analysis, when specified,

26.2.4 Tensile Properties,

26.2.5 Width of the gage length, when longitudinal strip tension test specimens are used,

26.2.6 Flattening Test acceptable,

26.2.7 Reverse Flattening Test acceptable,

26.2.8 Flaring Test acceptable,

26.2.9 Flange Test acceptable,

26.2.10 Hardness Test values,

26.2.11 Hydrostatic Test pressure,

26.2.12 Non-destructive Electric Test method,

26.2.13 Impact Test results, and

26.2.14 Other test results or information required to be reported by the product specification.

26.3 Test results or information required to be reported by supplementary requirements, or other requirements designated in the purchase order or contract shall be reported, but may be reported in a separate document.

26.4 The certified test report shall include a statement of explanation for the letter added to the specification number marked on the tubes (see 29.3), when all of the requirements of the specification have not been completed. The purchaser must certify that all requirements of the specification have been completed before removal of the letter (that is, X, Y, or Z).

26.5 A test report, certificate of compliance, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document shall meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

27. Inspection

27.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

28. Rejection

28.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

28.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such material shall be a matter for agreement.

29. Product Marking

29.1 Each length of tube shall be legibly stenciled with the manufacturers's name or brand, the specification number, and grade. The marking need not include the year date of the specification. For tubes less than 1¼ in. [31.8 mm] in diameter and tubes under 3 ft. [1 m] in length, the required information may be marked on a tag securely attached to the bundle or box in which the tubes are shipped.

29.2 For austenitic tubes, the marking paint or ink shall not contain any harmful metal, or metal salts, such as zinc, lead, or copper, which cause corrosive attack on heating.

29.3 When it is specified that certain requirements of a specification adopted by the ASME Boiler and Pressure Vessel Committee are to be completed by the purchaser upon receipt of the material, the manufacturer shall indicate that all requirements of the specification have not been completed by a letter such as X, Y, or Z, immediately following the specification number. This letter may be removed after completion of all requirements in accordance with the specification. An explanation of specification requirements to be completed is provided in Section 26.

29.4 *Bar Coding*—In addition to the requirements in 29.1-29.3, bar coding is acceptable as a supplemental identification method. The purchaser may specifiy in the order a specific bar coding system to be used.

30. Packaging, Marking, and Loading

30.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with the procedures of Practices A 700.

31. Government Procurement

31.1 *Scale Free Pipe*:

31.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order, for agencies of the U.S. Government where scale free tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

31.1.2 Tube shall be ordered to outside diameter (OD) and wall thickness.

31.1.3 *Responsibility for Inspection*— Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility for ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept the material. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections and tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to the prescribed requirements.

31.1.4 *Sampling for Flattening and Flaring Test and for Visual and Dimensional Examination*—Minimum sampling for flattening and flaring tests and visual and dimensional examination shall be as follows:

Lot Size (pieces per lot)	Sample Size
2 to 8	Entire lot
9 to 90	8
91 to 150	12
151 to 280	19
281 to 500	21
501 to 1200	27
1201 to 3200	35
3201 to 10 000	38
10 001 to 35 000	46

In all cases, the acceptance number is zero and the rejection number is one. Rejected lots may be screened and resubmitted for visual and dimensional examination. All defective items shall be replaced with acceptable items prior to lot acceptance

31.1.5 *Sampling for Chemical Analysis*— One sample for chemical analysis shall be selected from each of two tubes chosen from each lot. A lot shall be all material poured from one heat.

31.1.6 *Sampling for Tension and Bend Test*— One sample shall be taken from each lot. A lot shall consist of all tube of the same outside diameter and wall thickness manufactured during an 8-h shift from the same heat of steel, and heat treated under the same conditions of temperature and time in a single charge in a batch type furnace, or heat treated under the same condition in a continuous furnace, and presented for inspection at the same time.

31.1.7 *Hydrostatic and Ultrasonic Tests*— Each tube shall be tested by the ultrasonic (when specified) and hydrostatic tests.

31.1.8 Tube shall be free from heavy oxide or scale. The internal surface of hot finished ferritic steel tube shall be pickled or blast cleaned to a free of scale condition equivalent to the CSa2 visual standard listed in SSPC-SP 6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

31.1.9 In addition to the marking in Specification A 530/A 530M, each length of tube ¼ in. outside diameter and larger shall be marked with the following listed information. Marking shall be in accordance with FED-STD-183 and MIL-STD-792. (*a*) Outside diameter, wall thickness, and length (*b*) Heat or lot identification number.

31.1.10 Tube shall be straight to within the tolerances specified in Table 8:

31.1.11 When specified, each tube shall be ultrasonically examined in accordance with MIL-STD-271, except that the notch depth in the calibration standard shall be 5 % of the wall thickness or 0.005 in., whichever is greater. Any tube which produces an indication equal to or greater than 100 % of the indication from the calibration standard shall be rejected.

31.1.12 The tube shall be free from repair welds, welded joints, laps, laminations, seams, visible cracks, tears, grooves, slivers, pits, and other imperfections detrimental to the tube as determined by visual and ultrasonic examination, or alternate tests, as specified.

31.1.13 Tube shall be uniform in quality and condition and have a finish conforming to the best practice for standard quality tubing. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, shallow pits, and scale pattern will not be considered injurious if the imperfections are removable within the tolerances specified for

TABLE 8 Straightness Tolerances

Specified OD (in.)	Specified Wall Thickness (in.)	Maximum Curvature in Any 3 ft (in.)	Maximum Curvature in Total Length (in.)
Up to 5.0, incl	Over 3 % OD to 0.5, incl	0.030	0.010 × length, ft
Over 5.0 to 8.0, incl	Over 4 % OD to 0.75, incl	0.045	0.015 × length, ft
Over 8.0 to 12.75, incl.	Over 4 % OD to 1.0, incl	0.060	0.020 × length, ft

wall thickness or 0.005 in., whichever is greater. The bottom of imperfections shall be visible and the profile shall be rounded and faired-in.

31.1.14 No weld repair by the manufacturer is permitted.

31.1.15 Preservation shall be level A or commercial, and packing shall be level A, B, or commercial, as specified. Level A preservation and level A or B packing shall be in accordance with MIL-STD-163 and commercial preservation and packing shall be in accordance with Practices A 700 or Practice D 3951.

32. Keywords

32.1 alloy steel tube; austenitic stainless steel; carbon steel tube; general delivery; stainless steel tube; steel tube

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 450/A 450M – 04, which may impact the use of this standard. (Approved October 1, 2004)

(*1*) Added 26.5.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 450/A 450M – 03, which may impact the use of this standard. (Approved March 1, 2004)

(*1*) Revised 5.2.

(*2*) Deleted 5.2.1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 450/A 450M – 02, which may impact the use of this standard. (Approved September 10, 2003)

(*1*) Added Terminology A 941 to Sections 3 and 8 as well as Referenced Documents.

(*2*) Added Section 3, Terminology. Renumbered subsequent sections accordingly.

Designation: A 437/A 437M – 06

Standard Specification for Alloy-Steel Turbine-Type Bolting Material Specially Heat Treated for High-Temperature Service[1]

This standard is issued under the fixed designation A 437/A 437M; 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 alloy-steel bolting material specially heat treated for high-temperature service, such as steam turbine, gas turbine, and similar uses. This material requires special processing and should not be used in general-purpose applications. The term "bolting material," as used in this specification, covers rolled or forged bars, bolts, nuts, screws, washers, studs, and stud bolts. The bars shall be hot wrought. The material may be further processed by centerless grinding or by cold drawing.

1.2 The high-temperature properties of the material covered by this specification are dependent upon special heat treatment, which is required. Although the high-temperature properties are not specified, they are implied by control of the chemistry, heat treatment, and room-temperature properties of the material.

NOTE 1—High-temperature tests shall not be required, unless made a matter of agreement between the manufacturer and the purchaser.

1.3 Three levels of bolting strength are covered, designated Grades B4B, B4C, and B4D. Selection will depend on the design and the stresses and service for which the product is to be used.

NOTE 2—When ordering material under this specification, or when incorporating this specification as a reference in any individual specification, the purchaser must designate the steel by identification symbol or analysis, or both, and definitely specify the minimum mechanical properties required as selected from Table 1.

1.4 Supplementary requirements of an optional nature are provided for use at the option of the purchaser. The supplementary requirements shall apply only when specified individually by the purchaser in the purchase order or contract.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 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.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range

3. Common Requirements

3.1 Material and Fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A 962/A 962M, this specification shall prevail.

4. Ordering Information

4.1 The inquiry and order should indicate the following:

4.1.1 Specification designation, grade and class, issue date and revision letter,

4.1.2 Quantity (weight or number of pieces),

4.1.3 Description (bars, bolts, nuts, etc.),

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved March 1, 2006. Published March 2006. Originally approved in 1959. Last previous edition approved in 2004 as A 437/A 437M – 04.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-437 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.

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

TABLE 1 Tensile Requirements

Grade	Diameter, in. [mm]	Tensile Strength, min, ksi [MPa]	Yield Strength (0.2 % offset) min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Reduction of Area, min, %
B4B	...	145 [1000]	105 [720]	13	30
B4C	...	115 [790]	85 [585]	18	50
B4D	2½ [65] and under	125 [860]	105 [720]	18	50
	over 2½ to 4 [65 to 100]	110 [760]	95 [655]	17	45
	over 4 to 7 [100 to 180]	100 [690]	85 [585]	16	45

4.1.4 Dimensions,
4.1.5 Finish, and
4.1.6 Impact testing of nuts, if required (see Section 9).

5. Discard

5.1 A sufficient discard shall be made from each ingot to ensure freedom from injurious piping and undue segregation.

6. Heat Treatment

6.1 The material Grades B4B and B4C shall be heated to a temperature range of 1875 to 1925 °F [1025 to 1050 °C] and liquid quenched to below 600 °F [316 °C]. The material Grades B4B and B4C shall then be uniformly reheated for tempering at a tempering temperature at least 100 °F [55 °C] higher than the proposed operating temperature but not less than 1150 °F [620 °C], then air or furnace cooled to room temperature. The material shall be at the tempering temperature for a minimum of 2 h. Double tempering may be used to enhance properties.

6.2 Material Grade B4D shall be heated to a temperature range of 1700 to 1750 °F [925 to 954 °C] and oil quenched. The material shall then be uniformly reheated or tempered at a temperature of 1200 °F [650 °C] minimum, followed by air or furnace cooling to room temperature.

6.3 Stress relieving treatment of the bar material is required after any stretcher, roller, or rotary-straightening or cold-finishing operations performed after heat treatment for mechanical properties. Local gagging or press straightening to correct camber limitations in excess of 1/4 in. in any 5 ft [6 mm in any 1.5 m] shall be followed by a stress relieving heat treatment. The minimum stress relieving temperature shall be 100 °F [55 °C] below the minimum tempering temperature as shown in 6.1 for Grades B4B and B4C or in 6.2 for Grade B4D.

7. Chemical Composition

7.1 The material shall conform to the requirements as to chemical composition specified in Table 2.

8. Tensile Requirements

8.1 The material shall conform to the requirements as to tensile properties prescribed in Table 1 at room temperature after heat treatment.

8.2 The longitudinal axis of the test specimen shall be parallel to the direction of rolling.

TABLE 2 Chemical Requirements[A]

Element	Grades B4B, B4C[B]		Grade B4D	
	Range, %	Product Variation, %, Over or Under	Range, %	Product Variation, %, Over or Under
Carbon	0.20–0.25	0.02	0.36–0.44	0.02
Manganese	0.50–1.00	0.03	0.45–0.70	0.03
Phosphorus, max	0.025	0.005 over	0.04	0.005 over
Sulfur, max	0.025	0.005 over	0.04	0.005 over
Silicon	0.20–0.50	0.05	0.20–0.35	0.02
Nickel	0.50–1.00	0.03	...	...
Chromium	11.0–12.5	0.15	0.80–1.15	0.05
Molybdenum	0.90–1.25	0.05	0.50–0.65	0.03
Vanadium	0.20–0.30	0.03	0.25–0.35	0.03
Tungsten	0.90–1.25	0.05	...	...
Aluminum, max[C]	0.05	...	0.015	...
Titanium, max	0.05	...	...	...
Tin, max	0.04	...	...	...

[A] Steel to which lead has been added shall not be used.
[B] UNS S42200.
[C] Total, Soluble + Insoluble

9. Impact Requirements

9.1 The material Grades B4B, B4C, and B4D shall conform to the requirements as to impact properties prescribed in Table 3 at room temperature after heat treatment.

10. Hardness Tests

10.1 The material Grades B4B, B4C, and B4D shall conform to the requirements as to hardness as prescribed in Table 4 and Table 5 at room temperature after heat treatment.

11. Workmanship, Finish, and Appearance

11.1 Standard permissible variations of bars shall be as set forth in Table 6.

12. Nuts and Washers

12.1 When specified by the purchaser, the nuts shall be subject to the impact and tension requirements of this specification. The tests shall be made on test specimens taken from the bar or plate used in the manufacture of the nuts.

13. Threads

13.1 All threads shall be formed after heat treatment.

14. Nondestructive Inspection

14.1 Each bar or forged blank of starting material shall be subjected to NDE following final heat treatment. The method used shall be either the Eddy Current (EC), the Magnetic Particle (MPI) (wet or dry), the Liquid Penetrant (LPI), the Ultrasonic (UT), or the Visual Testing (VT), at the option of the producer. For LPI or MPI, linear indications (those indications longer than 1⁄16 in. [1.5 mm] with a length greater than three

TABLE 3 Impact Requirements

Grade	Minimum Impact Value, ft·lbf [J]
B4B	10 [14]
B4C	25 [34]
B4D[A]	25 [34]

[A] For bars over 5-in. [127-mm] diameter only.

TABLE 4 Hardness Requirements for Bolts and Studs

Grade	Brinell Hardness Number, max
B4B	331
B4C	277
B4D	302

TABLE 5 Hardness Requirements for Nuts and Washers

Grade	Brinell Hardness Number	Rockwell Hardness Number
B4B	293–341	C 31–37
B4C	229–277	C 21–29
B4D	263–311	C 27–33

times their width) are unacceptable. For UT or ET, reject levels for linear indications shall be based on the alarm response from a surface notch with a maximum depth of 0.012 in. [.30 mm] in a calibration bar. Product being subjected to VT shall be pickled prior to inspection. VT indications longer than ⅛ in. are prohibited.

TABLE 6 Permissible Variations in Size of Hot-Rolled Bars

Specified Size, in. [mm]	Permissible Variations from Specified Size, in. [mm]		Out of Round, in. [mm]
	Over	Under	
5⁄16 [8] and under	0.005 [0.13]	0.005 [0.13]	0.008 [0.20]
Over 5⁄16 to 7⁄16 [8 to 11] incl	0.006 [0.15]	0.006 [0.15]	0.009 [0.23]
Over 7⁄16 to 5⁄8 [11 to 16] incl	0.007 [0.18]	0.007 [0.18]	0.010 [0.25]
Over 5⁄8 to 7⁄8 [16 to 22] incl	0.008 [0.20]	0.008 [0.20]	0.012 [0.30]
Over 7⁄8 to 1 [22 to 25] incl	0.009 [0.23]	0.009 [0.23]	0.013 [0.33]
Over 1 to 1⅛ [25 to 29] incl	0.010 [0.25]	0.010 [0.25]	0.015 [0.38]
Over 1⅛ to 1¼ [29 to 32], incl	0.011 [0.28]	0.011 [0.28]	0.016 [0.41]
Over 1¼ to 1⅜ [32 to 35], incl	0.012 [0.30]	0.012 [0.30]	0.018 [0.46]
Over 1⅜ to 1½ [35 to 38], incl	0.014 [0.36]	0.014 [0.36]	0.021 [0.53]
Over 1½ to 2 [38 to 50], incl	1⁄64 [0.4]	1⁄64 [0.4]	0.023 [0.58]
Over 2 to 2½ [50 to 65], incl	1⁄32 [0.8]	0	0.023 [0.58]
Over 2½ to 3½ [65 to 90], incl	3⁄64 [1.2]	0	0.035 [0.89]
Over 3½ to 4½ [90 to 115], incl	1⁄16 [1.6]	0	0.046 [1.17]
Over 4½ to 5½ [115 to 140], incl	5⁄64 [2.0]	0	0.058 [1.47]
Over 5½ to 6½ [140 to 165], incl	⅛ [3.2]	0	0.070 [1.78]
Over 6½ to 7½ [165 to 190], incl	5⁄32 [4.0]	0	0.085 [2.16]

15. Keywords

15.1 bolts—steel; chromium alloy steel; fasteners—steel; marking on fasteners; nuts—steel; steel bars—alloy; steel bolting material; temperature service applications—high; turbine materials

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order; in which event the specified tests shall be made before shipment of the product.

S1. Non-Destructive Examination

S1.1 NDE is required following all machining and threading. The acceptance criteria of 14.1 shall apply.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 437/A 437M – 04, that may impact the use of this specification. (Approved March 1, 2006)

(*1*) Revised paragraph 3.1.

Designation: A 426/A 426M – 07

Standard Specification for Centrifugally Cast Ferritic Alloy Steel Pipe for High-Temperature Service[1]

This standard is issued under the fixed designation A 426/A 426M; 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 centrifugally cast alloy steel pipe intended for use in high-temperature, high-pressure service.

1.2 Several grades of ferritic steels are covered. Their compositions are given in Table 1.

1.3 Supplementary Requirements S1 through S12 are provided. The supplementary requirements provide for additional tests of an optional nature and when desired shall be so stated in the order (Section 4).

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 each other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 609/A 609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

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

E 94 Guide for Radiographic Examination

E 165 Test Method for Liquid Penetrant Examination

E 186 Reference Radiographs for Heavy-Walled (2 to 4½-in. [51 to 114-mm]) Steel Castings

E 208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

E 280 Reference Radiographs for Heavy-Walled (4½ to 12-in. [114 to 305-mm]) Steel Castings

E 446 Reference Radiographs for Steel Castings Up to 2 in. [51 mm] in Thickness

E 709 Guide for Magnetic Particle Examination

2.2 *ANSI Standard:*[4]

B46.1 Surface Texture

2.3 *ASME Boiler and Pressure Vessel Code:*[5]

Section IX Welding Qualifications

3. Ordering Information

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

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

3.1.2 Name of material (centrifugally cast pipe),

3.1.3 Specification number,

3.1.4 Grade (Table 1),

3.1.5 Size (outside or inside diameter and minimum wall thickness),

3.1.6 Length (specific or random) (Section on Permissible Variations in Length of Specification A 999/A 999M),

3.1.7 End finish (Section on Ends of Specification A 999/A 999M),

3.1.8 Optional Requirements S1 through S12 and Section 14.1,

3.1.9 Test report required (Section on Certified Test Report of Specification A 999/A 999M),

3.1.10 Service temperature if over 1000°F [540°C] (Note 1), and

[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 A01.18 on Castings.

Current edition approved May 1, 2007. Published May 2007. Originally approved in 1958. Last previous edition approved in 2005 as A 426/A 426M - 05.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-426 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 National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three 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

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Grade	UNS Number	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Chromium	Molybdenum	Other
		Composition, %							
CP1	J12521	0.25 max	0.30-0.80	0.040	0.045	0.10-0.50	. . .	0.44-0.65	. . .
CP2	J11547	0.10–0.20	0.30-0.61	0.040	0.045	0.10-0.50	0.50-0.81	0.44-0.65	. . .
CP5	J42045	0.20 max	0.30-0.70	0.040	0.045	0.75 max	4.00-6.50	0.45-0.65	. . .
CP5b	J51545	0.15 max	0.30-0.60	0.040	0.045	1.00-2.00	4.00-6.00	0.45-0.65	. . .
CP9	J82090	0.20 max	0.30-0.65	0.040	0.045	0.25-1.00	8.00-10.00	0.90-1.20	. . .
CP91	J84090	0.08–0.12	0.30–0.60	0.030	0.010	0.20–0.50	8.0–9.5	0.85–9.5	nickel, 0.40 max.; columbium, 0.060–0.10; nitrogen, 0.030–0.070; vanadium, 0.18–0.25; aluminum, 0.02 max.; titanium, 0.01 max; zirconium, 0.01 max.
CP11	J12072	0.05–0.20	0.30-0.80	0.040	0.045	0.60 max	1.00-1.50	0.44-0.65	. . .
CP12	J11562	0.05–0.15	0.30-0.61	0.040	0.045	0.50 max	0.80-1.25	0.44-0.65	. . .
CP15	J11522	0.15 max	0.30-0.60	0.040	0.045	0.15-1.65	. . .	0.44-0.65	. . .
CP21	J31545	0.05–0.15	0.30-0.60	0.040	0.045	0.50 max	2.65-3.35	0.80-1.06	. . .
CP22	J21890	0.05–0.15	0.30-0.70	0.040	0.045	0.60 max	2.00-2.75	0.90-1.20	. . .
CPCA15	J91150	0.15 max	1.00 max	0.040	0.040	1.50 max	11.5-14.0	0.50 max	. . .

3.1.11 Special requirements or additions to specification.

4. General Requirements for Delivery

4.1 Material furnished under 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 *Heat-Treatment*—The pipe shall be furnished in the normalized and tempered or liquid-quenched and tempered condition (Note 1). The temperature for tempering shall not be less than 1250°F [675°C] except for Grades CP1, CP2, CP11, CP12, and CP15 for which the temperature for tempering shall not be less than 1100°F [595°C]. Grade CP91 shall be normalized at 1900 – 1975 °F (1040 – 1080 °) and tempered at 1350 – 1470 °F (730 – 800 °C).

5.1.1 Heat treatment shall be performed after the pipe has been allowed to cool below the transformation range. Definition of heat-treatment terms shall be as given in Terminology A 941.

NOTE 1—Except for Grade CP91, it is recommended that the temperature for tempering should be at least 100°F [55°C] above the intended service temperature. The purchaser shall advise the manufacturer of the service temperature when it is over 1000°F [540°C].

5.2 *Machining*—The pipe shall be machined on the inner and outer surfaces to a roughness value no greater than 250 µ in. [6.35 µm] arithmetical average deviation (AA) from the mean line unless otherwise specified as in ANSI B46.1.

6. Chemical Analysis

6.1 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of elements specified in Table 1. The analysis shall be made on a test sample taken preferable during the pouring of the heat. The chemical composition thus determined shall conform to the requirements specified in Table 1 (Note 2).

NOTE 2—The role of alloying elements in the development of Grade CP91 has been extensively investigated. V and Nb contribute to precipitation strengthening by forming fine and coherent precipitation of M(C,N)X carbo-nitrides in the ferrite matrix. V also precipitates as VN during tempering or during creep. Therefore, the addition of strong nitride forming elements, those with a stronger affinity for nitrogen than Nb and V, as deoxidation agents, interferes with these high-temperature strengthening mechanisms.[6]

[6] Viswanathan, R. and Bakker, W. T., Materials for Ultra Supercritical Fossil Power Plants, EPRI, Palo Alto, CA: 2000, TR-114750.

6.2 *Product Analysis*—A product analysis may be made by the purchaser. The sample for analysis shall be selected so as to be representative of the pipe being analyzed. The chemical composition thus determined shall conform to the requirements of Table 1.

7. Tensile and Hardness Requirements

7.1 Steel used for the castings shall conform to the tensile and hardness requirements specified in Table 2.

8. Permissible Variations in Dimensions

8.1 *Thickness*—The wall thickness shall not vary over that specified by more than ⅛ in. [3 mm]. There shall be no variation under the specified wall thickness.

9. Number of Tests

9.1 One tension and one hardness test shall be made from each heat.

9.2 If a specimen is machined improperly or if flaws are revealed by machining or during testing, the specimen may be discarded and another substituted from the same heat.

10. Retests

10.1 If the results of the mechanical tests for any heat do not conform to the requirements specified, the castings may be reheat-treated and retested, but may not be re-austenitized more than twice.

11. Test Specimens

11.1 Test coupons from which tension test specimens are prepared shall be removed from heat-treated casting prolongations.

11.2 When agreed upon between the manufacturer and the purchaser, test coupons from which test specimens are prepared shall be cast attached to separate blocks from the same heat as the casting represented. The test blocks shall be heat treated in the same manner as the casting represented.

11.3 Tension test specimens shall be machined to the form and dimensions of the standard round 2-in. [50-mm] gage length specimens shown in Fig. 6 of Test Methods and Definitions A 370.

TABLE 2 Tensile Properties and Hardness Requirements

Tensile strength, min, psi [MPa]:	
Grade CP1	65 000 [450]
Grades CP11, CP22	70 000 [485]
Grades CP5, CP9, CPCA15	90 000 [620]
Grade CP91	85 000 [585] to 110 000 [760]
All other grades	60 000 [415]
Yield strength, min, psi [MPa]:	
Grade CP1	35 000 [240]
Grades CP11, CP22	40 000 [275]
Grades CP5, CP9	60 000 [415]
Grade CPCA15	65 000 [450]
Grade CP91	60 000 [415]
All other grades	30 000 [205]
Elongation, min, %:[A]	
Grade CP1	24
Grades CP11, CP22	20
Grades CP5, CP9, CP91, CPCA15	18
All other grades	22
Reduction of area, min, %:	
Grades CP1, CP2, CP11, CP12, CP15, CP21, CP22, CP5, CP5b, CP7, CP9	35
Grade CPCA15	30
Grade CP91	45
Hardness, max, HB:	
Grades CP5, CP5b, CP9, CP91, CPCA15	225
All other grades	201

[A] Elongation in 2 in. [50 mm] using a standard round specimen, in either the transverse or longitudinal direction.

12. Hydrostatic Test

12.1 Each length of pipe shall be hydrostatically tested in accordance with Specification A 999/A 999M.

12.2 When agreed to between the manufacturer and the purchaser and so stated in the order, the hydrostatic test may be deferred and shall be performed later by the purchaser. Pipe furnished without the hydrostatic test shall include with the mandatory marking the letters "NH." The manufacturer is responsible for the satisfactory performance of the casting when it is tested.

12.3 When certification is required by the purchaser and the hydrostatic test has been omitted, the certification shall clearly state "not hydrostatically tested." The specification number and material grade shown on the certification shall be followed by the letters "NH."

13. Visual Inspection

13.1 The surface of the casting shall be free from cracks and hot tears as determined by visual examination. Other surface imperfections shall be judged in accordance with visual acceptance criteria which may be specified in the order.

14. Rework and Retreatment

14.1 Defects as defined in Section 14 shall be removed and their removal verified by visual inspection of the resultant cavities. Defects that are located by inspecting with supplementary requirements S6, S7, S8, or S9 shall be removed or reduced to an acceptable size.

14.2 If removal of the defect does not infringe upon the minimum wall thickness, the depression may be blended uniformly into the surrounding surface.

14.3 If the cavity resulting from defect removal infringes upon the minimum wall thickness, weld repair is permitted subject to the purchaser's approval. The composition of the weld rod used shall be suitable for the composition of the metal being welded.

14.3.1 Only welders and procedures qualified in accordance with *ASME Boiler and Pressure Vessel Code*, Section IX, shall be used. All repair welds will be inspected to the same quality standards used to inspect the casting.

14.4 Local or full heat treatment in accordance with tempering temperatures specified in 5.1 shall follow welding.

15. Rejection

15.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the pipe may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

16. Product Marking

16.1 Each length of pipe shall be legibly marked with the manufacturer's name or brand, the specification number and grade. In addition, heat numbers or serial numbers that are traceable to heat numbers shall be marked on each length of pipe.

17. Keywords

17.1 alloy steel; centrifugal; ferritic; high-temperature service; pipe; stainless steel; steel castings

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon between the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

S1. Additional Tension Tests

S1.1 Additional tension tests shall be made at a temperature to be specified by the customer, and the properties to be met are a matter of agreement between the purchaser and manufacturer.

S2. Flattening Test

S2.1 The flattening test shall be made on specimens from one or both ends of each length of pipe. If the specimen from any end of any length fails to conform to the requirements of Specification A 999/A 999M, that length shall be rejected.

S3. Photomicrographs

S3.1 The manufacturer shall furnish one photomicrograph at 100 diameters from one specimen of as-finished pipe from each heat in each heat-treatment lot. Such photomicrographs shall be suitable identified as to pipe size, wall thickness, and heat. Such photomicrographs are for information only, to show the actual metal structure of the pipe as furnished. No photomicrographs for the individual pieces purchased shall be required except as specified in Section S4.

S4. Photomicrographs for Individual Pieces

S4.1 The manufacturer shall furnish photomicrographs from one or both ends of each pipe. All photomicrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S5. Metal Structure and Etching Tests

S5.1 Etching tests shall be made on transverse sections from the pipe and shall reveal the macrostructure of the material. Such tests are for information only.

S6. Radiographic Examination

S6.1 The castings shall be examined for internal defects by means of X rays or gamma rays. The inspection procedure shall be in accordance with Guide E 94 and the types and degrees of discontinuities considered shall be judged by Reference Radiographs E 186, E 280, or E 446. The extent of the examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser.

S7. Liquid Penetrant Examination

S7.1 The castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The method of performing the liquid penetrant test shall be in accordance with Practice E 165. The areas to be inspected, the methods and types of liquid penetrants to be used, the developing procedure, and the basis for acceptance shall be as specified on the inquiry or invitation to bid and on the purchase order or contract or both, or as agreed upon between the manufacturer and purchaser.

S8. Magnetic Particle Inspection

S8.1 The castings shall be examined by magnetic particle inspection. The inspection procedure used shall be in accordance with Practice E 709. The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser.

S9. Ultrasonic Inspection

S9.1 The castings shall be examined ultrasonically in accordance with Practice A 609/A 609M. The extent of the examination and the basis of acceptance shall be subject to agreement between the manufacturer and the purchaser.

S10. Residual Elements

S10.1 An analysis for the elements specified in Table S1 shall be included in those analyses specified in Section 6. The

TABLE S1 Residual Elements

Grade	Copper, max	Nickel, max	Chromium, max	Tungsten, max	Total Contents of These Unspecified Elements, max, %
CP1	0.50	0.50	0.35	0.10	1.00
CP2	0.50	0.50	. . .	0.10	1.00
CP5	0.50	0.50	. . .	0.10	1.00
CP5b	0.50	0.50	. . .	0.10	1.00
CP7	0.50	0.50	. . .	0.10	1.00
CP9	0.50	0.50	. . .	0.10	1.00
CP11	0.50	0.50	. . .	0.10	1.00
CP12	0.50	0.50	. . .	0.10	1.00
CP15	0.50	0.50	0.35	0.10	1.00
CP21	0.50	0.50	. . .	0.10	1.00
CP22	0.50	0.50	. . .	0.10	1.00
CPCA15	0.50	1.00	. . .	0.10	1.50

chemical composition thus determined shall conform to the requirements of Table S1.

S11. Charpy Impact Test

S11.1 Charpy impact test properties shall be determined on each heat from a set of three Charpy V-notch specimens. The test coupons shall be taken as specified for tension specimens in Section 11 and tested at a test temperature agreed upon by the manufacturer and purchaser. The acceptance requirements shall be either energy absorbed or lateral expansion or percent shear area, and shall be that agreed upon by the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A 370.

S11.2 *Absorbed Energy Value*, of three specimens shall not be less than that agreed upon by the manufacturer and purchaser, with no more than one value permitted below the minimum average specified and no value permitted below the minimum specified for a single specimen.

S11.3 *Lateral Expansion Value*, shall be agreed upon by the manufacturer and purchaser.

S11.4 *Percent Shear Area*, shall be agreed upon by the manufacturer and purchaser.

S12. Drop Weight Test

S12.1 Drop weight test properties shall be determined by preparing and testing either Type P1, P2, or P3 specimens in accordance with Test Method E 208. The test coupons shall be taken as specified for tension specimens in Section 11. The crack starter weld shall be deposited on the surface of the specimen which was nearest to the casting surface. Each test shall consist of at least two specimens tested at a temperature agreed upon by the manufacturer and purchaser. Each specimen shall exhibit a "no break" performance.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue, A 426/A 426M - 05, that may impact the use of this standard. (Approved May 1, 2007)

(*1*) Added Grade CP91 to 5.1 and 6.1 and to Tables S1 and 2.

(*2*) Added UNS numbers to Table S1.

Designation: A 423/A 423M – 95 (Reapproved 2004)

Standard Specification for Seamless and Electric-Welded Low-Alloy Steel Tubes[1]

This standard is issued under the fixed designation A 423/A 423M; 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

1.1 This specification[2] covers minimum-wall-thickness, seamless and electric-resistance welded, low-alloy steel tubes for pressure containing parts such as economizers or other applications where corrosion resistance is important.

1.2 The tubing sizes and thicknesses usually furnished to this specification are ½ to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.500 in. [0.9 to 12.7 mm] inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ¼ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 An optional supplementary requirement is provided and, when desired, shall be so stated in the order.

1.5 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:* [3]

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing

3. Ordering Information

3.1 Orders for material under this specification shall 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 electric-resistance-welded tubes),

3.1.3 Grade (Table 1),

3.1.4 Manufacture (hot finished or cold finished),

3.1.5 Size (outside diameter and minimum wall thickness),

3.1.6 Length (specific or random),

3.1.7 Optional requirements (hydrostatic or electric test, 13.7),

3.1.8 Test report required (see Certification Section of Specification A 450/A 450M),

3.1.9 Specification designation, and

3.1.10 Special requirements and any supplementary requirements selected.

4. Manufacture

4.1 Tubes made by the seamless process may be hot finished or cold finished.

5. Heat Treatment

5.1 All tubes shall be normalized or given such heat treatment as may be necessary to conform to the requirements of this specification.

6. Chemical Composition

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

7. Product Analysis

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

7.2 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

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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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Sept 1, 2004. Published October 2004. Originally approved in 1958. Last previous edition approved in 2000 as A 423/A 423M – 95 (2000).

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-423 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.

TABLE 1 Chemical Requirements

	Composition, %	
	Grade 1	Grade 2
Carbon, max	0.15	0.15
Manganese, max	0.55	0.50–1.00
Phosphorus	0.06–0.16	0.04 max
Sulfur, max	0.060	0.05
Silicon, min	0.10	...
Copper	0.20–0.60	0.30–1.00
Chromium	0.24–1.31	...
Nickel	0.20–0.70	0.40–1.10
Molybdenum, min	...	0.10

the requirements of the specification; otherwise all remaining material in the heat or lot (Note 1) shall be rejected or, at the option of the producer, 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.

NOTE 1—For flattening, flaring, and flange requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness that 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.

NOTE 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 that 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.

8. Tensile Requirements

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

9. Hardness Requirements

9.1 The tubes shall have a hardness number not exceeding 170 HB or 87 HRB.

TABLE 2 Number of Tubes in a Lot Heat Treated by the Continuous Process

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
Less than 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 wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

TABLE 3 Tensile Requirements

Tensile strength, min, ksi [MPa],	60 [415]
Yield strength, min, or 50 mm, ksi [MPa]	37 [255]
Elongation in 2 in. or 50 mm, min, %	25
For longitudinal 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 points shall be made	1.25[A]

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

10. Forming Operations

10.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws.

11. Mechanical Tests Required

11.1 *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 (Note 2).

11.2 *Flattening Test*—One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring or flanging test, from each lot (Note 1).

11.3 *Flaring Test (Seamless Tubes)*—One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

11.4 *Flange Test (Welded Tubes)*—One flange test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (Note 1).

11.5 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (Note 2).

11.6 *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.

11.7 *Hydrostatic or Nondestructive Electric Test*—Each tube shall be subjected to the hydrostatic test, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser.

12. General Requirements

12.1 Material furnished under this specification should conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

13. Product Marking

13.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall include whether hot finished or cold finished, and whether seamless or welded.

14. Keywords

14.1 seamless steel tube; steel tube; alloy; welded steel tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser in the inquiry, contract, or order. Details of this supplemental requirement shall be agreed upon by the manufacturer and the purchaser.

S1. Surface Condition

S1.1 If pickling or shot blasting, or both, are required, this shall be specifically stated in the order and shall be done at the purchaser's expense.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered unless specified in the order and the necessary tests shall be made at the mill.

S2. Additional Testing of Welded Tubing per ASME Request

S2.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 450/A 450M.

S2.2 If Practice E 273 is employed, a 100 % volumetric inspection of the entire length of each tube shall also be performed using one of the non-destructive electric tests permitted by Specification A 450/A 450M.

S2.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S2.4 In addition to the marking prescribed in Specification A 450/A 450M, "S2" shall be added after the grade designation.

Designation: A 420/A 420M – 07

Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service[1]

This standard is issued under the fixed designation A 420/A 420M; 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 wrought carbon steel and alloy steel fittings of seamless and welded construction, covered by the latest revision of ASME B 16.9, ASME B 16.11, MSS-SP-79, MSS-SP-83, and MSS-SP-95. Fittings differing from these ASME and MSS standards shall be furnished in accordance with Supplementary Requirement S58 of Specification A 960/A 960M. These fittings are for use in pressure piping and pressure vessel service at low temperatures.

1.2 Optional supplementary requirements are provided for fittings where a greater degree of examination is desired. When desired, one or more of these supplementary requirements shall be specified in the order.

1.3 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

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.

2. Referenced Documents

2.1 In addition to those Referenced Documents listed in Specification A 960/A 960M, the following list of standards apply to this specification.

2.2 *ASTM Standards:* [3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 960/A 960M Specification for Common Requirements for Wrought Steel Piping Fittings

2.3 *ASME Standards:*

B 16.9 Factory-Made Wrought Steel Butt-Welding Fittings[4]

B 16.11 Forged Steel Fittings, Socket-Welding Threaded[4]

Section VIII Division 1, Pressure Vessels[4]

Section IX Welding Qualifications

2.4 *MSS Standards:*

MSS-SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions[5]

MSS-SP-79 Socket Welding Reducer Inserts[5]

MSS-SP-83 Steel Pipe Unions, Socket-Welding and Threaded[5]

MSS-SP-95 Swage(d) Nipples and Bull Plugs[5]

2.5 *ASNT Standards:*

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification[6]

3. Ordering Information

3.1 See Specification A 960/A 960M.

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 960/A 960M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 960/A 960M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 960/A 960M, this specification shall prevail.

5. Material

5.1 The material for fittings shall consist of forgings, bars, plates, seamless or fusion welded tubular products with filler metal added. It shall conform to the chemical requirements in Table 1, and be made by one of the following processes:

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved March 1, 2007. Published April 2007. Originally approved in 1958. Last previous edition approved in 2006 as A 420/A 420M – 06.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-420 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, Three Park Ave., New York, NY 10016-5990.

[5] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602.

[6] Available from 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

NOTE 1—All requirements are maximum unless otherwise indicated.
NOTE 2—Where an ellipsis (...) appears in this table, there is no requirement.

Grade[A]	Composition, %										
	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	Cb	V
WPL6	0.30	0.50–1.35	0.035	0.040	0.15–0.40	0.40	0.30	0.12	0.40	0.02[B]	0.08
WPL9	0.20	0.40–1.06	0.030	0.030	. . .	1.60–2.24			0.75–1.25		
WPL3[C]	0.20	0.31–0.64	0.05	0.05	0.13–0.37	3.2–3.8			. . .		
WPL8[D]	0.13	0.90	0.030	0.030	0.13–0.37	8.4–9.6			. . .		

[A] When fittings are of welded construction, the symbols above shall be supplemented by the letter "W".
[B] By agreement, the limit for Columbium may be increased up to 0.05 % on heat analysis and 0.06 % on product analysis.
[C] Fittings made from plate or forgings may have 0.90 % max manganese.
[D] Fittings made from plate may have 0.98 % max manganese.

open-hearth, basic-oxygen, or electric-furnace. The steels shall be made using recognized melting practices necessary to produce steels that shall meet the impact requirements of this specification.

6. Manufacture

6.1 Forging or forming operations shall be performed by hammering, pressing, piercing, extruding, upsetting, working, bending, fusion-welding, or machining, or by a combination of two or more of these operations. The forming procedure shall be so applied that it will not produce injurious defects in the fittings.

6.2 All welds, including welds in tubular products from which fittings are made, shall be (*1*) made by welders, welding operators and welding procedures qualified under the provisions of ASME Section IX, (*2*) heat treated in accordance with Section 7 of this specification, and (*3*) nondestructively examined throughout the entire length of each weld in accordance with Section 14 of this specification. The radiography of welds shall be done either prior to or after forming at option of manufacturer. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

6.3 The welded joints of the fittings shall be finished in accordance with the requirements of Paragraph UW-35 (a) of Section VIII, Division 1 of ASME Boiler and Pressure Vessel Code.

6.4 All butt-weld tees manufactured by cold-forming methods shall be liquid penetrant or magnetic particle examined by one of the methods specified in Supplementary Requirement S52 or S53 of Specification A 960/A 960M. This examination shall be performed after final heat treatment by NDE personnel qualified under the provisions of SNT-TC-1A. Only the sidewall areas of the tee need be examined. This area is defined by a circle that covers the area from the weld bevel of the branch outlet to the centerline of the body or run. Internal and external surfaces shall be examined when size permits accessibility. After the removal of any cracks, the tees shall be re-examined by the original method. Acceptable tees shall be marked with the symbol PT or MT, as applicable, to indicate compliance.

6.5 Stubends may be produced with the entire lap added by the welding of a ring, made from plate or bar of the same alloy grade and composition, to the outside of a straight section of pipe, provided the weld is double welded, is a full penetration joint, satisfies the requirements of 6.2 for qualifications and radiography and 7.1 for post weld heat treatment.

7. Heat Treatment

7.1 All fittings shall be furnished in the normalized, normalized and tempered, annealed, or quenched and tempered condition. All welding shall be completed prior to the austenitizing heat treatment.

7.2 The full thickness of the material from which impact test specimens are to be obtained shall be heat treated with a furnace charge as specified in 10.4.2 or 10.4.3.

7.3 After forming, the fittings shall be allowed to cool below the lower critical before applying one of the heat treatments listed in 7.1.

7.4 When the fittings are to be post-weld heat treated after being welded by the purchaser and when so specified in the order, the test specimens shall be subjected to the same post-weld heat treatment. The purchaser shall use the post-weld heat treatment shown in Table 2, unless otherwise specified in the order.

8. Chemical Composition

8.1 The steel shall conform to requirements of chemical composition for the respective material prescribed in Table 1.

8.2 The steel shall not contain any unspecified elements for the ordered grade to the extent that it then conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

8.3 The chemical composition of weld metal is not required to meet the same limits of the base materials however, the composition of the weld deposit shall be such that it meets the minimum mechanical and impact requirements of this specification. In general, the alloy content shall be similar to that of the base metal but shall not exceed 6 % except in the case of fittings of 9 % nickel steel.

8.4 A product analysis is optional.

TABLE 2 Post-Weld Heat Treatment

Grade	Metal Temperature		Minimum Holding Time
	°F	°C	
WPL6	1100–1200	595–650	1 h/in. [25 mm] ¾ h min
WPL3	1100–1150	540–620	¼ h/in. [25 mm] 1 h min
WPL8	1050–1100	565–595	½ h/in. [25 mm] 1 h min
WPL9[A]	1025–1085	550–585	1 h/in. [25 mm] 2 h min

[A] 2 in. [51 mm] thickness and over. The cooling rate shall not be less than 300 °F [150 °C] per hour down to a temperature of 600 °F [315 °C].

9. Tensile Properties

9.1 The tensile properties of the fittings material shall conform to the requirements for the applicable grade of material as listed in Table 3.

9.2 At least one tension test shall be made on each heat of material and in the same condition of heat treatment as the finished fittings it represents provided that the wall thickness of the fitting and the representative sample thickness do not vary more than 1/4 in. [6 mm]. At least one tension test per heat of weld metal shall be made after heat treatment in the same manner as the base metal. Results need not be reported unless Supplementary Requirement S51 of Specification A 960/A 960M is specified.

9.3 Records of the tension tests shall be certification that the material of the fitting meets the tensile requirements of this specification.

10. Impact Test Properties

10.1 *Properties*:

10.1.1 The notched bar impact properties of the base metal and weld metal shall conform to the requirements of Table 4 or Table 5 for the applicable grade of material.

10.1.2 *Retest*—When the average value of the three specimens equals or exceeds the minimum value permitted for a single specimen and the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, a retest of three additional specimens shall be made. The value for each of these retest specimens shall equal or exceed the required average value. When an erratic result is caused by a defective specimen, or there is uncertainty in test procedure, a retest shall be allowed.

10.2 *Procedures*:

TABLE 3 Tensile Requirements

NOTE 1—Where an ellipsis (. . .) appears in this table, there is no requirement.

Requirement	Grade WPL6	Grade WPL9	Grade WPL3	Grade WPL8
Tensile strength, min ksi [MPa]	60 [415] − 95 [655]	63 [435] − 88 [610]	65 [450] − 90 [620]	100 [690] − 125 [865]
Yield strength, min ksi [MPa]	35 [240]	46 [315]	35 [240]	75 [515]

Elongation Requirements	Grades							
	WPL6		WPL9		WPL3		WPL8	
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
Standard round specimen, or small proportional specimen, min % in 4 D	22	12	20	. . .	22	14	16	. . .
Rectangular specimen for wall thickness 5/16 in. [7.94 mm] and over, and for all small sizes tested in full section; min % in 2 in. or 50 mm	30	16.5	28	18	30	20	22	. . .
Rectangular specimen for wall thickness less than 5/16 in [7.94 mm]; min % in 2 in. or 50 mm (1/2-in. [12.7- mm] wide specimen)	[A]	[A]	[A]	[A]	[A]	[A]	[A]	. . .

[A] For each 1/32 in. [0.79 mm] decrease in wall thickness below 5/16 in. [7.94 mm], a deduction of 1.5 % (grades WPL6, WPL9, and WPL3) or 1.25 % (WPL8) for longitudinal and 1.0 % (grades WPL6, WPL9 and WPL3) for transverse from the values shown above is permitted. The following table gives the minimum value for various wall thicknesses:

Wall Thickness in	Wall Thickness [mm]	WPL6 Longitudinal	WPL6 Transverse	WPL9 Longitudinal	WPL9 Transverse	WPL3 Longitudinal	WPL3 Transverse	WPL8 Longitudinal	WPL8 Transverse
5/16 (0.312)	[7.94]	30.0	16.5	28.0	18.0	30.0	20.0	22.0	. . .
9/32 (0.281)	[7.14]	28.5	15.5	26.5	17.0	28.5	19.0	20.75	. . .
1/4 (0.250)	[6.35]	27.0	14.5	25.0	16.0	27.0	18.0	19.5	. . .
7/32 (0.219)	[5.56]	25.5	. . .	23.5	. . .	25.5	. . .	18.25	. . .
3/16 (0.188)	[4.76]	24.0	. . .	22.0	. . .	24.0	. . .	17.0	. . .
5/32 (0.156)	[3.97]	22.5	. . .	20.5	. . .	22.5	. . .	15.75	. . .
1/8 (0.125)	[3.17]	21.0	. . .	19.0	. . .	21.0	. . .	14.5	. . .
3/32 (0.094)	[2.38]	19.5	. . .	17.5	. . .	19.5	. . .	13.25	. . .
1/16 (0.062)	[1.59]	18.0	. . .	16.0	. . .	18.0	. . .	12.0	. . .

Note—The preceding table gives the computed minimum elongation value for each 1/32 in. [0.79 mm] decrease in wall thickness. Where the wall thickness lies between two values above, the minimum elongation value is determined by the following equations:

Direction of Test	Equations WPL6	Equations WPL9	Equations WPL3	Equations WPL8
Longitudinal	E = 48t + 15.00	48t + 13.00	E = 48t + 15.00	40t + 9.50
Transverse	t = 32t + 6.50	32t + 8.00	E = 32t + 10.00	. . .

where:

E = elongation in 2 in. or 50 mm, %, and

t = actual thickness of specimen, in.

TABLE 4 Charpy Impact Requirements for WPL6, WPL9, and WPL3[A]

Size of Specimen, mm	Charpy V-Notch Impact Value Required for Acceptance (Average of Three Specimens)		Minimum Charpy V-Notch Impact Value Without Requiring Retest (One Specimen Only of a Set)	
	ft·lbf	J	ft·lbf	J
10 by 10.0	13	17.6	10	13.6
10 by 7.5	10	13.6	8	10.8
10 by 5.0	7	9.5	5	7.0
10 by 2.5	4	5.4	3	4.1

[A] Straight-line interpolation for intermediate values is permitted.

TABLE 5 Charpy Impact Requirements for WPL8

Size of Specimen, mm	Charpy V-Notch Impact Value Required for Acceptance (Average of Specimens)		Minimum Charpy V-Notch Impact Value Without Requiring Retest (One Specimen Only of a Set)	
	ft·lbf	J	ft·lbf	J
10 by 10.0	25.0	33.9	20.0	27.1
10 by 7.5	21.0	28.5	17.0	23.1
10 by 5.0	17.0	23.1	14.0	19.0
10 by 2.5	8.0	10.8	6.0	8.1

10.2.1 All material furnished under this specification shall be tested for impact resistance at the temperature for the respective grade in Table 6. Exceptions to these requirements are permissible when agreed upon between the purchaser and producer and specified in the order, in that the impact test is acceptable when made at temperatures different from those shown in Table 6, provided the test temperature is at least as low as the intended service temperature, and fittings are suitably marked in accordance with Section 18 to identify the reported test temperature.

10.2.2 The notched-bar impact test shall be made in accordance with the procedure for the simple-beam, Charpy-type test of Test Methods and Definitions A 370. Each impact test shall consist of breaking three specimens.

10.3 *Specimens*:

10.3.1 Notched-bar impact specimens shall be simple-beam, Charpy-type A with a V-notch in accordance with Test Methods and Definitions A 370. 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 standard subsize impact specimens shall be used. When the size or shape of the finished fittings is insufficient to permit obtaining the smallest standard subsize impact specimens, an impact test by the fitting manufacturer will not be required. The material from which the specimens are taken shall be heat treated with a furnace charge in accordance with 10.4.2 or 10.4.3. Impact tests shall be made from either the raw material from which the fittings are made or from a finished fitting at the option of the manufacturer.

TABLE 6 Impact Test Temperature

Grade	Impact Test Temperature, °F [°C]
WPL6	−50 [−45]
WPL9	−100 [−75]
WPL3	−150 [−100]
WPL8	−320 [−195]

10.3.2 Test specimens shall be obtained so that the longitudinal axis of the specimen is parallel to the longitudinal axis of the fitting while the axis of the "V" shall be perpendicular to the surface. On wall thickness over 1 in. [25 mm] the specimens shall be obtained with their longitudinal axis located ½ in. [13 mm] from the outer surface.

10.3.3 When testing welds, the notch of the specimen shall be in the welded joint and, where the diameter and wall thickness permit, the longitudinal axis of the specimen shall be transverse to the longitudinal axis of the weld. The axis of the notch shall be perpendicular to the surface.

10.4 *Number of Tests*:

10.4.1 A notched-bar impact test, consisting of breaking three specimens shall be made. Each test shall represent only such fittings from a heat that do not vary from the thickness of the material from which the test specimens are taken by more than ¼ in. [6 mm].

10.4.2 When heat treatment is performed in furnaces not equipped with calibrated recording pyrometers, one impact test shall be made for each heat in each heat-treatment load. Test specimens shall be included with each furnace charge. If this heat treatment is conducted in continuous-type furnaces not equipped with calibrated recording pyrometers, then one test per heat shall be conducted for each 5000 lb or 2550 kg (or less) of product.

10.4.3 When heat treatment is performed in furnaces controlled within a 50 °F [28 °C] range and equipped with calibrated recording pyrometers so that records of heat treatment are available, then one impact test from each heat is required, provided that all other heat treatments are conducted at the same temperatures and within the same 50 °F [28 °C] range as the furnace charge that contained the test specimens.

10.4.4 On fittings of welded construction, additional impact tests of the same number as required in 10.4.1 or 10.4.2 shall be made to test the weld metal.

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

10.5 *Retreatment*:

10.5.1 If the results of impact tests conducted in accordance with 10.4.2 and 10.4.3 fail to conform to the test requirements specified in 10.1, that group of fittings shall be retreated and submitted for test. No group of fittings shall be retreated more than twice.

11. Hydrostatic Tests

11.1 Hydrostatic testing of fittings is not required by this specification.

11.2 All fittings shall be capable of withstanding without failure, leakage, or impairment of their serviceability, a hydrostatic test pressure equal to that prescribed for the specified matching pipe of equivalent material.

12. Dimensions

12.1 Butt-welding fittings and butt-welding short-radius elbows and returns purchased in accordance with this specification shall conform to the dimensions and tolerances given in the latest revision of ASME B 16.9 or MSS-SP-95. Steel socket-welding and threaded fittings purchased in accordance with this specification shall conform to the sizes, shapes, dimensions, and tolerances specified in the latest revision of ASME B 16.11, MSS-SP-79, or MSS-SP-83.

12.2 Fittings of size or shape differing from these standards, but meeting all other requirements of the specification, shall be furnished in accordance with Supplementary Requirement S58 of Specification A 960/A 960M only by agreement with the purchaser.

13. Surface Quality

13.1 See Specification A 960/A 960M.

13.2 *Repair by Welding (Base Metal)*:

13.2.1 Repair welding, by the manufacturer, is permissible for parts made to dimensional standards such as those of ASME or equivalent standards.

13.2.2 Prior approval of the purchaser shall be required to weld repair special parts made to the purchaser's dimensional requirements.

13.2.3 Welding shall be accomplished with a weld procedure designed to produce low hydrogen in the weldment. Short circuit gas metal arc welding is permissible only with the approval of the purchaser.

13.2.4 The weld repair shall be permanently identified with the welder's stamp or symbol in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

13.2.5 After weld repair, material shall be heat treated in accordance with 7.1.

13.2.6 Tension and impact testing of representative deposited weld metal for each heat shall meet the requirements of 9.2 and 10.1.

14. Radiographic Examination

14.1 All fusion-welded butt joints shall be radiographically examined throughout the entire length in accordance with Paragraph UW-51 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code. Instead of radiographic examination, welds made by the manufacturer may be ultrasonically examined in accordance with Appendix 12 of Section VIII, Division 1, of the ASME Boiler and Pressure Vessel Code. In general, radiography or ultrasonic examination shall be performed after all forming operations have been completed. Fittings made from fusion-welded pipe need not be radiographed if the pipe has been radiographed, provided the fitting forming process does not materially affect the weld.

15. Inspection

15.1 All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to.

15.2 Other tests, when required by agreement shall be made from materials of the lots covered in the order.

16. Rejection and Rehearing

16.1 Material that fails to conform to the requirements of this specification shall be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier shall make claim for a rehearing.

16.2 Fittings that develop defects in shop working or application operations shall be rejected. Upon rejection, the manufacturer shall be notified promptly in writing.

17. Certification

17.1 Test reports are required for all fittings covered by this specification. Each test report shall include the following information:

17.1.1 Chemical analysis results, Section 8 (Table 1),

17.1.2 Tensile property results, Section 9 (Table 3) report yield strength and ultimate strength in ksi [MPa] and elongation in percent,

17.1.3 Impact test results, Section 10 (Table 4 and Table 5),

17.1.4 Type heat treatment, Section 7,

17.1.5 Radiographic examination statement, Section 14,

17.1.6 Any supplemental testing required by the purchase order, and

17.1.7 Statement that the fitting was manufactured, sampled, tested, and inspected in accordance with the specification and was found to meet the requirements.

17.2 Certification shall state whether welds have been examined radiographically or ultrasonically.

17.3 Letters of compliance and test results shall state the specification number, year of issue, revision letter (if any), grade and class of the fittings.

18. Product Marking

18.1 All fittings shall have the prescribed information marked on each fitting in accordance with MSS-SP-25, latest revision.

18.1.1 Fittings shall be marked by any method which will permanently identify the fittings and not result in sharp discontinuities. Stamping, when used, shall be done with blunt-nosed continuous or blunt-nosed interrupted dot stamps.

18.1.2 When agreed upon between the purchaser and producer, and specified in the order, the markings shall be painted or stenciled on the fitting or stamped on a metal or plastic tag which shall be securely attached to the fitting.

18.2 The prescribed information for butt-welding fittings shall be: the manufacturer's name or trademark (see Note 1), material designation or grade, schedule number or nominal wall thickness designation, and the heat number or manufacturer's heat identification. Fittings containing welds that have been ultrasonically examined instead of radiography shall be marked U after heat identity.

NOTE 1—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component complies with this specification.

18.3 The prescribed information for threaded or socket welding fittings shall be: the manufacturer's name or trademark, material designation or grade, pressure class or schedule number, and size.

18.4 When size does not permit complete marking, identification marks shall be omitted in the reverse order of those listed above and in accordance with MSS-SP-25.

18.5 The impact test temperature shall also be shown if it is different from the standard test temperature specified in Table 6, for example: WPL-6-60 or WPL3-176.

18.6 *Bar Coding*—In addition to the requirements in 18.1, 18.2, 18.3, 18.4, and 18.5, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

19. Keywords

19.1 pipe fittings; piping applications; pressure containing parts; pressure vessel service; temperature service applications, low

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements appearing in Specification A 960/A 960M may be included in the order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirement details not fully described shall be agreed upon between the purchaser and the supplier.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 420/A 420M – 06, that may impact the use of this specification. (Approved March 1, 2007)

(*1*) Added MSS-SP-83 to 1.1 and 12.1.
(*2*) Revised 2.5 to delete the year date of SNT-TC-1A.
(*3*) Revised17.1.7 to clarify that a certificate of compliance is required to be part of the MTR.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 420/A 420M – 05, that may impact the use of this specification. (Approved March 1, 2006)

(*1*) Revised the wording in paragraph 17.1 and added paragraph 17.1.7 to add mandatory reporting requirements.

Standard Specification for Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service[1]

This standard is issued under the fixed designation A 409/A 409M; 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 straight seam or spiral seam electric-fusion-welded, light-wall, austenitic chromium-nickel alloy steel pipe for corrosive or high-temperature service. The sizes covered are NPS 14 to 30 with extra light (Schedule 5S) and light (Schedule 10S) wall thicknesses. Table X1.1 shows the wall thickness of Schedule 5S and 10S pipe. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

1.2 Several grades of alloy steel are covered as indicated in Table 1.

1.3 Optional supplementary requirements are provided. These call for additional tests to be made, and when desired shall be 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 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]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

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

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *ASME Boiler and Pressure Vessel Code:*

Section IX Welding Qualifications. [4]

2.3 *AWS Standards:*[5]

A 5.22 Flux Cored Arc Welding

A 5.30 Consumable Weld Inserts for Gas Tungsten Arc Welding

A 5.4 Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes

A 5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes

A 5.11 Nickel and Nickel-Alloy Covered Welding Electrodes

A 5.14 Nickel and Nickel-Alloy Bare Welding Rods and Electrodes

2.4 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[6]

3. Ordering Information

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

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

3.1.2 Name of material (straight seam or spiral seam electric-fusion-welded austenitic steel pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (outside diameter and schedule number, or wall thickness).

3.1.5 Length (specific or random) (Section 11),

[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.

Current edition approved Sept. 1, 2005. Published October 2005. Originally approved in 1957 . Last previous edition approved in 2001 as A 409/A 409M – 01.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-409 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, Three Park Ave., New York, NY 10016-5990.

[5] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.

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

TABLE 1 Chemical Requirements

	UNS Designations[A]	Composition, %											
		Carbon, max	Manganese, max	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum	Titanium	Columbium	Cerium	Other Elements
TP304	S30400	0.08	2.00	0.045	0.030	1.00 max	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .
TP304L	S30403	0.035	2.00	0.045	0.030	1.00 max	8.0–12.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00 max	12.0–16.0	22.0–24.0		. . .	. . .	. . .	Cb 10 × C min, 1.10 max
TP309S	S30908	0.08	2.00	0.045	0.030	1.00 max	12.0–15.0	22.0–24.0		. . .	. . .	. . .	
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0		. . .	. . .	. . .	Cb 10 × C min, 1.10 max
TP310S	S31008	0.08	2.00	0.045	0.030	1.00 max	19.0–22.0	24.0–26.0		. . .	. . .	. . .	
TP316	S31600	0.08	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	
TP316L	S31603	0.035	2.00	0.045	0.030	1.00 max	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .
TP317	S31700	0.08	2.00	0.045	0.030	1.00 max	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .	...
TP321	S32100	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–20.0	. . .	[B]	. . .	. . .	. . .
TP347	S34700	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	. . .	. . .	[C]	. . .	. . .
TP348	S34800	0.08	2.00	0.045	0.030	1.00 max	9.00–12.0	17.0–19.0	. . .	. . .	[D]	. . .	. . .
. . .	S31254	0.020	1.00	0.030	0.010	0.80 max	17.5–18.5	19.5–19.5	6.0–6.5	. . .	. . .	. . .	Cu 0.50–1.00 N 0.18–0.22
. . .	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0	. . .	. . .	. . .	0.03–0.08	N 0.14–0.20
. . .	S31725	0.030	2.00	0.045	0.030	1.00 max	13.5–17.5	18.0–20.0	4.0–5.0	. . .	. . .	. . .	N 0.020 max
. . .	S31726	0.030	2.00	0.045	0.030	1.00 max	14.5–17.5	17.0–20.0	4.0–5.0	. . .	. . .	. . .	N 0.10–0.20
. . .	S34565	0.030	5.0–7.0	0.030	0.010	1.00 max	16.0–18.0	23.0–25.0	4.0–5.0	. . .	0.10 max	. . .	N 0.40–0.60
. . .	N08367	0.030	2.00	0.040	0.030	1.00 max	23.5–25.5	20.0–22.0	6.0–7.0	. . .	. . .	. . .	Cu 0.75 max Ni 0.18–0.25
. . .	S20400	0.030	7.0–9.0	0.45	0.030	1.00 max	1.50–3.00	15.0–17.0	. . .	. . .	. . .	. . .	N 0.15–0.30

[A] New designation established in accordance with ASTM E 527 and SAE J1086.
[B] The titanium content shall be not less than 5 times the carbon content and not more than 0.70 %.
[C] The columbium plus tantalum content shall be not less than 10 times the carbon content and not more than 1.10 %.
[D] The columbium plus tantalum content shall be not less than 10 times the carbon content and not more than 1.10 %. The tantalum content shall be 0.10 % maximum, CO 0.20 % maximum.

3.1.6 End finish (Section on Ends of Specification A 999/A 999M),

3.1.7 Optional requirements (5.2.1-5.2.3 removal of weld bead; 5.3.2, special heat treatment; 15.2, nondestructive test; 10.1.1, outside diameter tolerance; 11.2, length circumferentially welded; 12.3, repair by welding and heat treatment subsequent to repair welding; 12.4, sand blasted or pickled; 17.1 Certification; Supplementary Requirements S1 to S6).

3.1.8 Specification designation, and

3.1.9 Special requirements.

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 If a specific type of melting is required by the purchaser it shall be stated on the order.

5.2 *Welding*:

5.2.1 The welds shall be made by the manual or automatic electric-welding process. For manual welding, the operator and procedure shall be qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX. Unless otherwise specified on the purchase order, the pipe may be welded with or without filler metal when the automatic electric-welding process is used.

5.2.2 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 1⁄16 in. [2 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 should be reasonably smooth and free from irregularities. The weld 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.

5.2.3 Weld defects, as determined by specified inspection requirements, shall be repaired by removal to sound metal and rewelding.

5.3 *Heat Treatment*:

5.3.1 Except as provided in 5.3.2, all pipe shall be furnished in the heat-treated condition. The heat-treatment procedure shall consist of heating the material to a minimum temperature of 1900°F [1040°C], except for S31254 and S30815 which shall be heat treated to 2100°F [1150°C] and 1920°F [1050°C] respectively, S24565 which shall be heat treated in the range 2050°F [1120°C] to 2140°F [1170°C], and N08367, which shall be heated to a minimum temperature of 2025°F [1107°C], all materials to be followed by quenching in water or rapidly cooling by other means.

5.3.2 The purchase order shall specify one of the following conditions if the heat-treated condition specified in 5.3.1 is not desired by the purchaser:

5.3.2.1 A final heat-treatment temperature under 1900°F [1040°C]. Each pipe supplied under this requirement shall be stenciled with the final heat-treatment temperature in degrees Fahrenheit or degrees Celsius after the suffix "HT". Controlled structural or special service characteristics may be specified as a guide for the most suitable heat treatment.

5.3.2.2 No final heat treatment of pipe fabricated of plate, that has been solution heat treated at temperatures required by this specification. Each pipe supplied under this requirement shall be stenciled with the suffix "HT-O".

5.3.2.3 No final heat treatment of pipe fabricated of plate, that has not been solution heat treated. Each pipe supplied under this requirement shall be stenciled with the suffix "HT-SO".

5.4 A solution annealing temperature above 1950°F [1065°C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP321, TP347, and TP348. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S5).

6. Chemical Composition

6.1 The steel shall conform to the chemical composition in Table 1.

6.2 When specified on the purchase order, a product analysis shall be supplied from one tube or coil of steel per heat. The product analysis tolerance of Specification A 480/A 480M shall apply.

6.3 Unless otherwise specified in the purchase order, the chemical composition of the welding filler metal shall conform to the requirements of the applicable AWS specification for the corresponding grade shown in Table 2. Grades with no filler metal classification indicated shall be welded with filler metals producing deposited weld metal having a composition in accordance with the chemical composition specified in Table 1. The method of analysis for nitrogen and cerium shall be a matter of agreement between the purchaser and manufacturer. The purchaser may choose a higher-alloy filler metal when needed for corrosion resistance.

7. Tensile Requirements

7.1 The tensile properties of the plate or sheet used in making the pipe shall conform to the requirements prescribed in Table 3. Certified mill test reports shall be submitted to the pipe manufacturer.

7.2 A transverse tension test taken across the welded joint of the finished pipe shall meet the same minimum tensile strength requirements as the sheet or plate. The weld section on the tension specimen shall be in the same condition as the finished pipe (with or without bead as specified).

8. Mechanical Tests Required

8.1 *Tension Test*—One transverse tension test of the weld shall be made on each lot (Note 2) of finished pipe.

NOTE 2—The term "lot" applies to each 200 ft [60 m] or less of pipe of the same NPS and wall thickness (or schedule number) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace. When final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge. When no heat treatment is performed following final forming operations, the lot shall include each 200 ft [60 m] or less of pipe

TABLE 2 Filler Metal Specifications

Grade	UNS Designation	Filler Metal Classification and UNS Designation^A for Applicable^B AWS Specification											
		A 5.4		A 5.9		A 5.11		A 5.14		A 5.22		A 5.30	
		Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS
TP304	S30400	E308	W30810	ER308	S30880 W30840	. . .	. . .	. . .	. . .	E308T	W30831	IN308	S30880
TP304L	S30403	E308L	W30813	ER308L	S30883 W30843	. . .	. . .	. . .	. . .	E308T	W30835	IN308L	S30883
TP309Cb	S30940	E309Cb	W30917	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP310Cb	S31040	E310Cb	W31017	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
TP316	S31600	E316	W31610	ER316	S31680 W31640	. . .	. . .	. . .	. . .	E316T	W31631	IN316	S31680
TP316L	S31603	E316L	W31603	ER316L	S31683 W31643	. . .	. . .	. . .	. . .	E316LT	W31635	IN316L	S31683
TP317	S31700	E317	W31700	ER317	S31783 W31743	. . .	. . .	. . .	. . .	E317T	W31731	IN317	S31780
TP321	S32100	E347	W34710	ER321 ER347	S32180 W32140 S34780 W34740	. . .	. . .	. . .	. . .	E347T	W34733	IN348	S34780
TP347	S34700	E347	W34710	ER347	S34780 W34740	. . .	. . .	. . .	. . .	E347T	W34733	IN348	S34780
TP348	S34800	E347	W34710	ER347	S34780 W34740	. . .	. . .	. . .	. . .	E347T	W34733	IN348	S34780
. . .	S31254	. . .	. . .	. . .	. . .	ENiCrMo-3	W86112	ERNiCrMo-3	NO6625	. . .	. . .	. . .	. . .
. . .	S31725	. . .	. . .	. . .	. . .	ENiCrMo-3	W86112	ERNiCrMo-3	NO6625	. . .	. . .	. . .	. . .
. . .	S31726	. . .	. . .	. . .	. . .	ENiCrMo-3	W86112	ERNiCrMo-3	NO6625	. . .	. . .	. . .	. . .
. . .	S24565	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	N08367	. . .	. . .	. . .	. . .	ENiCrMo-3	W86112	ErNiCrMo-3	N06625	. . .	. . .	. . .	. . .
. . .	S20400	E209	W32210	ER209	W32240	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

^{A}New designation established in accordance with Practice E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).
^{B}Choice of American Welding Society specification depends on the welding process used.

TABLE 3 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]
TP304	S30400	75 [515]	30 [205]
TP304L	S30403	70 [485]	25 [170]
TP309Cb	S30940	75 [515]	30 [205]
TP309S	S30908	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP316	S31600	75 [515]	30 [205]
TP316L	S31603	70 [485]	25 [170]
TP317	S31700	75 [515]	30 [205]
TP321	S32100	75 [515]	30 [205]
TP347	S34700	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
. . .	S31254	94 [650]	44 [300]
. . .	S30815	87 [600]	45 [310]
. . .	S31725	75 [515]	30 [205]
. . .	S31726	80 [550]	35 [240]
. . .	S24565	115 [795]	60 [415]
. . .	S20400	95 [655]	48 [330]
. . .	N08367		
	$t \leq 0.187$	100 [690]	45 [310]
	$t > 0.187$	95 [655]	45 [310]

of the same NPS and wall thickness (or schedule number) which is produced from the same heat of steel.

8.2 *Transverse Guided-Bend Weld Test*—One test (two specimens) of the weld shall be made on each lot (Note 2) of finished pipe.

8.3 *Pressure or Nondestructive Electric Test*—Each length of pipe shall be subjected to a pressure test or a nondestructive electric test as prescribed in Section 5.

9. Permissible Variations in Wall Thickness

9.1 The minimum wall thickness at any point shall not be more than 0.018 in. [0.46 mm] under the specified wall thickness. (This tolerance is slightly more than commercial tolerances on sheet and plate to allow for possible loss of thickness caused by manufacturing operations.)

10. Permissible Variations in Dimensions

10.1 Permissible variations in dimensions shall not exceed the following at any point in each length of pipe.

10.1.1 *Specified Diameter*—Where the specified wall thickness is less than 0.188 in. [4.8 mm], the actual outside diameter, based on circumferential measurement, shall not vary more than ±0.20 % from the specified outside diameter. Where the specified wall thickness is 0.188 in. [4.8 mm] and heavier, the actual outside diameter, based on circumferential measurement, may vary a maximum of ±0.40 % from the specified outside diameter. (Outside diameter tolerances closer than shown above may be obtained by agreement between the pipe manufacturer and purchaser.)

10.1.2 *Out-of-Roundness*—The difference between the major and the minor outside diameter shall not be more than 1.5 % of the specified outside diameter.

10.1.3 *Alignment* (*Camber*)—Using a 10-ft [3.0-m] straightedge placed so that both ends are in contact with the pipe, the camber shall not be more than 3⁄16 in. [4.8 mm].

11. Lengths

11.1 Unless otherwise specified in the purchase order, pipe of NPS 22 or less will be furnished in random lengths of 9 to 12 ft (Note 3). For outside diameters of over NPS 22, the minimum length will be 5 ft (Note 3).

NOTE 3—This value(s) applies when the inch-pound designation of this specification is the basis of purchase. The corresponding metric value(s) shall be agreed upon between the manufacturer and the purchaser.

11.2 When specified by the purchaser, two or more lengths may be circumferentially welded together to produce longer lengths.

11.3 Circumferentially welded joints shall be of the same quality as the longitudinal joints.

12. Workmanship, Finish, and Appearance

12.1 The finished pipe shall have a workmanlike finish.

12.2 *Repair of Defects by Machining or Grinding*—Pipe showing moderate slivers or other surface defects may be machined or ground inside or outside to a depth which will ensure the removal of all defects providing the wall thickness is not reduced below the minimum specified in 9.1.

12.3 *Repair of Defects by Welding*—Defects which violate minimum wall thickness may be repaired by welding, but only with the approval of the purchaser. Areas shall be suitably prepared for welding with tightly closed defects removed by grinding. Open, clean defects, such as pits or impressions, may require no preparation. All welders, welding operators, and weld procedures shall be qualified to the ASME Boiler and Pressure Vessel Code, Section IX. Unless the purchaser specifies otherwise, pipe required to be heat treated under the provisions of 5.3 shall be heat treated or reheat treated following repair welding. Repaired lengths, where repair depth is greater than ¼ of the thickness, shall be pressure tested or repressure tested after repair and heat treatment (if any). Repair welds shall also be examined by suitable non-destructive examination techniques, including any techniques specifically required of the primary weld.

12.4 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser may request that a passivating treatment be applied.

13. Test Specimens

13.1 Transverse tension and bend test specimens may be taken from a test plate of the same material as the pipe, made by attaching a formed cylinder to the end of the pipe and welding the abutting edges as a continuation and duplication of the seam of the pipe (run-off plate). As an alternative to a formed cylinder, the run-off plate may consist of flat plates with reinforcing bars clamped to the underside to prevent distortion. The run-off plate material shall be of the same heat, preferably shear croppings from the same plate.

13.2 When heat treatment is required, test specimens shall be cut from pipe after the heat treating has been completed, or specimens removed from the pipe prior to heat treating shall be heat treated with the pipe.

14. Transverse Guided-Bend Weld Tests

14.1 Two bend test specimens shall be taken transversely across the weld. One shall be subject to a face guided-bend test and the second to a root guided-bend test. One specimen shall be bent with the inside surface of the pipe against the plunger, and the other with the outside surface against the plunger.

14.2 The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. [3 mm] in any direction are present in the weld metal or between the weld and the pipe metal after bending. Cracks which originate along the edges of the specimen during testing, and that are less than ¼ in. [6.5 mm] measured in any direction shall not be considered.

15. Pressure Tests

15.1 Where hydrostatic test equipment is not available, the pipe may be air or gas pressure tested with an internal pressure of 100 psi [700 kPa]. The weld and weld area shall be inspected with the use of soap solution or any other prepared solution which will detect the leakage of air or gas from the inside.

15.2 Instead of a pressure test, when mutually agreed upon between the purchaser and manufacturer, the entire weld area of each pipe, including circumferential welds, may be tested by nondestructive testing methods. These methods shall be capable of detecting both surface and subsurface defects.

16. Inspection

16.1 When specified in the purchase order, the pipe may be inspected at the manufacturer's plant by an inspector representing the purchaser. The inspector shall have entry at all times. The manufacturer shall afford the inspector, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

17. Certification

17.1 Upon request of the purchaser in the contract or order, certification in accordance with the provisions of Specification A 999/A 999M shall be furnished. When specified on the purchase order or when a specific type of melting has been specified on the purchase order, the type of melting used shall also be reported to the purchaser or the purchaser's representative.

18. Product Marking

18.1 Each length of pipe manufactured in accordance with this specification shall have the following identifying marking within 12 in. [300 mm] of one end: manufacturer's name or trade-mark, specification number, grade number of the alloy, the manufacturer's heat number, size, and schedule number. Additional marking requirements for heat treatment are described in Supplementary Requirement S2.

18.2 Marking shall be legibly stenciled with a suitable paint or permanent marking compound, except when otherwise specified by the purchaser.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 At the request of the purchaser a product analysis of one coupon representing finished sheet or plate from each heat shall be made by the pipe manufacturer. The drillings for product analysis may be taken from shear crop or test specimens. The results of product analysis shall conform to the requirements in Table 1 and shall be reported to the purchaser.

S2. Radiographic Examination

S2.1 Weld soundness shall be determined through radiographic examination made in accordance with requirements as agreed upon between the pipe manufacturer and purchaser.

S3. Corrosion Requirements

S3.1 *Boiling Nitric Acid Test*—Except for Grade TP321, coupons representing finished pipe made of nonmolybdenum-bearing material (0.50 % and less molybdenum) shall meet the requirement of the boiling nitric acid test conducted according to Practice C of Practices A 262. The condition of the test specimens and the corrosion rates are as follows: Type 347 and Type 348 shall be tested in the sensitized condition (heated for 1 h at 1240°F [675°C]) and the rate of penetration shall not exceed 0.0020 in. [0.05 mm]/month. All other nonmolybdenum-bearing types, except for Grade TP321, shown in Table 1 shall be tested in the annealed and unsensitized condition and the rate of penetration shall not exceed 0.0015 in. [0.04 mm]/month.

S3.2 *Acidified Copper Sulfate Test*—Coupons representing finished pipe made of molybdenum-bearing material and Type 321 (over 0.50 % molybdenum) shall meet the requirements of the copper-copper sulfate-sulfuric acid test (intergranular corrosion test) conducted in accordance with Practice E of Practices A 262. The condition of the test specimen is as follows: All molybdenum-bearing types shown in Table 1 shall be tested in the annealed and unsensitized condition. Type 321 shall be tested in the sensitized condition (heated for 1 h at 1240°F [675°C]). All specimens shall meet the requirements of the prescribed bend test.

S4. Ferrite Control of Weld Deposits

S4.1 The ferrite content of the deposited weld metal in any length of pipe may be determined. The procedural details pertaining to this subject (that is, welding, plate and weld deposit chemistry, testing equipment and method, number and location of test sites, and ferrite control limits) shall be a matter for agreement between the purchaser and the manufacturer.

S5. Stabilizing Heat Treatment

S5.1 Subsequent to the heat treatment required in 5.3, Grades TP321, TP347, and TP348 shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S6 Intergranular Corrosion Test

S6.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S6.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S6.2 A stabilization heat treatment in accordance with Supplementary Requirement S5 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium.

APPENDIX

(Nonmandatory Information)

X1. Wall Thickness of Schedule 5S and Schedule 10S

TABLE X1.1 Pipe Dimensions

NPS Designator	Wall Thickness			
	Schedule 5S		Schedule 10S	
	in.	mm	in.	mm
14	0.156	3.96	0.188	4.78
16	0.165	4.19	0.188	4.78
18	0.165	4.19	0.188	4.78
20	0.188	4.78	0.218	5.54
22	0.188	4.78	0.218	5.54
24	0.218	5.54	0.250	6.35
30	0.250	6.35	0.312	7.92

Designation: A 403/A 403M – 07

Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings[1]

This standard is issued under the fixed designation A 403/A 403M; 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*

1.1 This specification covers wrought stainless steel fittings for pressure piping applications.[2]

1.2 Several grades of austenitic stainless steel alloys are included in this specification Grades are designated with a prefix, WP or CR, based on the applicable ASME or MSS dimensional and rating standards, respectively.

1.3 For each of the WP stainless grades, several classes of fittings are covered, to indicate whether seamless or welded construction was utilized. Class designations are also utilized to indicate the nondestructive test method and extent of nondestructive examination (NDE). Table 1 is a general summary of the fitting classes applicable to all WP grades of stainless steel covered by this specification. There are no classes for the CR grades. Specific requirements are covered elsewhere.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 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.

1.6 This specification does not apply to cast steel fittings. Austenitic stainless steel castings are covered in Specifications A 351/A 351M, A 743/A 743M, and A 744/A 744M.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 351/A 351M Specification for Castings, Austenitic, for Pressure-Containing Parts

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 743/A 743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application

A 744/A 744M Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 960/A 960M Specification for Common Requirements for Wrought Steel Piping Fittings

E 112 Test Methods for Determining Average Grain Size

E 165 Test Method for Liquid Penetrant Examination

2.2 *ASME Standards:* [4]

ASME B16.9 Factory-Made Wrought Steel Butt-Welding Fittings

ASME B16.11 Forged Steel Fittings, Socket-Welding and Threaded

2.3 *MSS Standards:* [5]

MSS SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions

MSS SP-43 Standard Practice for Light Weight Stainless Steel Butt-Welding Fittings

MSS SP-79 Socket-Welding Reducer Inserts

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-403 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, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[5] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602, http://www.mss-hq.com.

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

MSS SP-83 Steel Pipe Unions, Socket-Welding and Threaded
MSS SP-95 Swage(d) Nipples and Bull Plugs
2.4 *ASME Boiler and Pressure Vessel Code:* [4]
Section VIII Division I, Pressure Vessels
Section IX, Welding Qualifications
2.5 *AWS Standards:* [6]
A 5.4 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes
A 5.9 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes
2.6 *ASNT:* [7]
SNT-TC-1A (1984) Recommended Practice for Nondestructive Testing Personnel Qualification and Certification

3. Common Requirements and Ordering Information

TABLE 1 Fitting Classes for WP Grades

Class	Construction	Nondestructive Examination
S	Seamless	None
W	Welded	Radiography or Ultrasonic
WX	Welded	Radiography
WU	Welded	Ultrasonic

3.1 Material furnished to this specification shall conform to the requirements of Specification A 960/A 960M including any supplementary requirements that are indicated in the purchase order. Failure to comply with the common requirements of Specification A 960/A 960M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A 960/A 960M, this specification shall prevail.

3.2 Specification A 960/A 960M identifies the ordering information that should be complied with when purchasing material to this specification.

4. Material

4.1 The material for fittings shall consist of forgings, bars, plates, or seamless or welded tubular products that conform to the chemical requirements in Table 2. See Table 3 for a list of common names.

4.2 The steel shall be melted by one of the following processes:

4.2.1 Electric furnace (with separate degassing and refining optional),

4.2.2 Vacuum furnace, or

4.2.3 One of the former followed by vacuum or electroslag-consumable remelting.

4.3 If secondary melting is employed, the heat shall be defined as all ingots remelted from a primary heat.

5. Manufacture

5.1 *Forming*—Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion welding, machining, or by a combination of two or more of these operations. The forming procedure shall be so applied that it will not produce injurious defects in the fittings.

5.2 All fittings shall be heat treated in accordance with Section 6.

5.3 Grade WP fittings ordered as Class S shall be of seamless construction and shall meet all requirements of ASME B16.9, ASME B16.11, MSS SP-79, MSS SP-83, or MSS SP-95.

5.4 Grade WP fittings ordered as Class W shall meet the requirements of ASME B16.9 and:

5.4.1 Shall have all pipe welds made by mill or the fitting manufacturer with the addition of filler metal radiographically examined throughout the entire length in accordance with the Code requirements stated in 5.5, and,

5.4.2 Radiographic inspection is not required on single longitudinal seam welds made by the starting pipe manufacturer if made without the addition of filler metal; and

5.4.3 Radiographic inspection is not required on longitudinal seam fusion welds made by the fitting manufacturer when all of the following conditions have been met:

5.4.3.1 No addition of filler metal,

5.4.3.2 Only one welding pass per weld seam, and,

5.4.3.3 Fusion welding from one side only.

5.4.4 In place of radiographic examination, welds made by the fitting manufacturer may be ultrasonically examined in accordance with the Code requirements stated in 5.6.

5.5 Grade WP fittings ordered as Class WX shall meet the requirements of ASME B16.9 and shall have all welds, whether made by the fitting manufacturer or the starting material manufacturer, radiographically examined throughout their entire length in accordance with Paragraph UW-51 of Section VIII, Division I, of the ASME Boiler and Pressure Vessel Code.

5.6 Grade WP fittings ordered as Class WU shall meet the requirements of ASME B16.9 and shall have all welds, whether made by the fitting manufacturer or the starting material manufacturer, ultrasonically examined throughout their entire length in accordance with Appendix 12 of Section VIII, Division 1 of ASME Boiler and Pressure Vessel Code.

5.7 The radiography or ultrasonic examination of welds for this class of fittings may be done at the option of the manufacturer, either prior to or after forming.

5.8 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

5.9 Grade CR fittings shall meet the requirements of MSS SP-43 and do not require nondestructive examination.

5.10 All fittings shall have the welders, welding operators, and welding procedures qualified under the provisions of Section IX of the ASME Boiler and Pressure Vessel Code except that starting pipe welds made without the addition of filler metal do not require such qualification.

[6] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, http://www.aws.org.

[7] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

TABLE 2 Chemical Requirements

NOTE 1—Where an ellipsis (...) appears in this table, there is no requirement.

Grade[A]			Composition, %										
Grade WP	Grade CR	UNS Designation	C[B]	Mn[B]	P[B]	S[B]	Si[B]	Ni	Cr	Mo	Ti	N_2C[C]	Others
WPXM-19	CRXM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	11.5–13.5	20.5–23.5	1.50–3.00	. . .	0.20–0.40	[D]
WP304	CR304	S30400	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .
WP304L	CR304L	S30403	0.030[E]	2.00	0.045	0.030	1.00	8.0–12.0	18.0–20.0	. . .	. . .	. . .	. . .
WP304H	CR304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .
WP304N	CR304N	S30451	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	. . .	. . .	0.10–0.16	. . .
WP304LN	CR304LN	S30453	0.030	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0	. . .	. . .	0.10–0.16	. . .
WP309	CR309	S30900	0.20	2.00	0.045	0.030	1.00	12.0–15.0	22.0–24.0	. . .	. . .	. . .	. . .
WP310S	CR310S	S31008	0.08	2.00	0.045	0.030	1.00	19.0–22.0	24.0–26.0	. . .	. . .	. . .	. . .
WPS31254	CRS31254	S31254	0.020	1.00	0.030	0.010	0.80	17.5–18.5	19.5–20.5	6.0–6.5	. . .	0.18–0.22	Cu 0.50–1.00
WP316	CR316	S31600	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .
WP316L	CR316L	S31603	0.030[E]	2.00	0.045	0.030	1.00	10.0–14.0[F]	16.0–18.0	2.00–3.00	. . .	. . .	. . .
WP316H	CR316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00-3.00	. . .	. . .	. . .
WP316N	CR316N	S31651	0.08	2.00	0.045	0.030	1.00	10.0–13.0	16.0–18.0	2.00–3.00	. . .	0.10-0.16	. . .
WP316LN	CR316LN	S31653	0.030	2.00	0.045	0.030	1.00	10.0–13.0	16.0–18.0	2.00–3.00	. . .	0.10–0.16	. . .
WP317	CR317	S31700	0.08	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .
WP317L	CR317L	S31703	0.030	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0	. . .	. . .	. . .
WPS31725	CRS31725	S31725	0.030	2.00	0.045	0.030	1.00	13.5–17.5	18.0–20.0	4.0–5.0	. . .	0.20	. . .
WPS31726	CRS31726	S31726	0.030	2.00	0.045	0.030	1.00	13.5–17.5	17.0–20.0	4.0–5.0	. . .	0.10–0.20	. . .
WP321	CR321	S32100	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	. . .	[G]	. . .	. . .
WP321H	CR321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	. . .	[H]	. . .	. . .
WPS33228	CRS33228	S33228	0.04–0.08	1.00	0.020	0.015	0.30	31.0–33.0	26.0–28.0	. . .	. . .	. . .	Ce 0.05–0.10 Al 0.025 Cb 0.6–1.0
WPS34565	CRS34565	S34565	0.030	5.0–7.0	0.030	0.010	1.00	16.0–18.0	23.0–25.0	4.0–5.0	. . .	0.40–0.60	Cb 0.10
WP347	CR347	S34700	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	. . .	. . .	. . .	[I]
WP347H	CR347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	. . .	. . .	. . .	[J]
WP348	CR348	S34800	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	. . .	. . .	. . .	Cb+Ta=10×(C)−1.10 Ta 0.10 Co 0.20
WP348H	CR348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0	. . .	. . .	. . .	Cb+Ta=8×(C)−1.10 Ta 0.10 Co 0.20
WPS38815	CRS38815	S38815	0.030	2.00	0.040	0.020	5.5-6.5	13.0-17.0	13.0-15.0	0.75-1.50	. . .	. . .	Cu 0.75-1.50 Al 0.30

[A] See Section 15 for marking requirements.
[B] Maximum, unless otherwise indicated.
[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
[D] Columbium 0.10–0.30 %; Vanadium, 0.10–0.30 %.
[E] For small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.24 mm] in average wall thickness.
[F] On pierced tubing, the nickel may be 11.0–16.0 %.
[G] $5X(C+N_2)–0.70$.
[H] $4X(C+N_2)–0.70$.
[I] The columbium content shall be not less than ten times the carbon content and not more than 1.10 %.
[J] The columbium content shall be not less than eight times the carbon content and not more than 1.10 %.

5.11 All joints welded with filler metal shall be finished in accordance with the requirements of Paragraph UW-35 (a) of Section VIII, Division I, of the ASME Boiler and Pressure Vessel Code.

5.12 Fittings machined from bar shall be restricted to NPS 4 or smaller. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

5.12.1 All caps machined from bar shall be examined by liquid penetrant in accordance with Supplementary Requirement S52 in Specification A 960/A 960M.

5.13 Weld buildup is permitted to dimensionally correct unfilled areas produced during cold forming of stub ends. Radiographic examination of the weld buildup shall not be required provided that all the following steps are adhered to:

TABLE 3 Common Names

Grade WP[A]	Grade CR[A]	UNS Designation	Type[B]
WPXM-19	CRXM-19	S20910	XM-19[C]
WP304	CR304	S30400	304
WP304L	CR304L	S30403	304L
WP304H	CR304H	S30409	304H
WP304N	CR304N	S30451	304N
WP304LN	CR304LN	S30453	304LN
WP309	CR309	S30900	309
WP310S	CR310S	S31008	310S
WPS31254	CRS31254	S31254	...
WP316	CR316	S31600	316
WP316L	CR316L	S31603	316L
WP316H	CR316H	S31609	316H
WP316N	CR316N	S31651	316N
WP316LN	CR316LN	S31653	316LN
WP317	CR317	S31700	317
WP317L	CR317L	S31703	317L
WPS31725	CRS31725	S31725	317LM[C]
WPS31726	CRS31726	S31726	317LMN[C]
WP321	CR321	S32100	321
WP321H	CR321H	S32109	321H
WPS33228	CRS33228	S33228	...
WPS34565	CRS34565	S34565	...
WP347	CR347	S34700	347
WP347H	CR347H	S34709	347H
WP348	CR348	S34800	348
WP348H	CR348H	S34809	348H

[A] Naming system developed and applied by ASTM International.
[B] Unless otherwise indicated, a grade designation originally assigned by the American Iron and Steel Institute (AISI).
[C] Common name, not a trademark widely used, not associated with any one producer.

5.13.1 The weld procedure and welders or welding operators meet the requirements of 5.10.

5.13.2 Annealing is performed after welding and prior to machining.

5.13.3 All weld surfaces are liquid penetrant examined in accordance with Appendix 8 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

5.13.4 Repair of areas in the weld is permitted, but 5.13.1, 5.13.2, and 5.13.3 must be repeated.

5.14 Stub ends may be produced with the entire lap added as weld metal to a straight pipe section provided the welding satisfies the requirements of 5.10 for qualifications and Section 6 for post weld heat treatment.

5.14.1 *Grade WP Class W*—Radiographic inspection of the weld is required. See 5.4.

5.14.2 *Grade WP Class WX*—Radiographic inspection of all welds is required. See 5.5.

5.14.3 *Grade WP Class WU*—Ultrasonic inspection of all welds is required. See 5.6.

5.14.4 *Grade CR*—Nondestructive examination is not required. See 5.12.1.

5.15 Stub ends may be produced with the entire lap added by the welding of a ring, made from plate or bar of the same alloy grade and composition, to the outside of a straight section of pipe, provided the weld is double welded, is a full penetration joint, satisfies the requirements of 5.10 for qualifications and Section 6 for post weld heat treatment.

5.15.1 *Grade WP Class W*—Radiographic inspection of the welds, made with the addition of filler metal, is required (see 5.4).

5.15.2 *Grade WP Class WX*—Radiographic inspection of all welds, made with or without the addition of filler metal, is required (see 5.5).

5.15.3 *Grade WP Class WU*—Ultrasonic inspection of all welds, made with or without the addition of filler metal, is required (see 5.6).

5.15.4 Grade CR nondestructive examination is not required (see 5.9).

5.16 After final heat treatment, all "H-Grade" steel fittings shall have a grain size of 7 or coarser in accordance with Test Methods E 112.

6. Heat Treatment

6.1 All fittings shall be furnished in the heat-treated condition. For H grades, separate solution heat treatments are required for solution annealing; in-process heat treatments are not permitted as a substitute for the separate solution annealing treatments. The heat-treat procedure, except for those grades listed in 6.2, shall consist of solution annealing the fittings at a minimum temperature of 1900 °F [1040 °C] until the chromium carbides go into solution, and then cooling at a sufficient rate to prevent reprecipitation.

6.2 A solution annealing temperature above 1950 °F [1065 °C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in 321, 321H, 347, and 347H. When specified by the purchaser, a lower temperature stabilization or resolution anneal shall be used subsequent to the initial high-temperature solution anneal (see Supplementary Requirement S2).

6.3 All welding shall be done prior to heat treatment.

6.4 Fittings machined directly from solution-annealed forgings and bar stock need not be resolution annealed.

7. Chemical Composition

7.1 The chemical composition of each cast or heat used shall be determined and shall conform to the requirements of the chemical composition for the respective grades of materials listed in Table 2. The ranges as shown have been expanded to include variations of the chemical analysis requirements that are listed in the various specifications for starting materials (pipe, tube, plate, bar, and forgings) normally used in the manufacturing of fittings to this specification. Methods and practices relating to chemical analyses required by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751. Product analysis tolerances in accordance with Specification A 480/A 480M are applicable.

7.2 The steel shall not contain any unspecified elements for the ordered grade to the extent that it conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

7.3 In fittings of welded construction, the alloy content (carbon, chromium, nickel, molybdenum, columbium, and tantalum) of the deposited weld metal shall conform to that required of the base metal or for equivalent weld metal as given in the AWS filler metal specification A 5.4 or A 5.9 (Type 348 weld metal is listed in AWS A 5.9 but not in AWS A 5.4). Exceptions are when welding on Types 304L and 304 base metals, the deposited weld metal shall correspond, respectively, to AWS E308L(ER308L) and E308 (ER308), when welding on Type 321 base metal, the weld metal shall correspond to AWS Type E347 (ER347 or ER321); and, when welding on S31725, S31726, S31254 or S33228 deposited weld metal shall correspond either to the alloy content of the base metal or to AWS A5.11 E NiCrMo·3 (UNS W86112) (AWS A5.14 Ni Cr Mo·3 (UNS N06625)). On S38815 base metals, the deposited weld metal and filler metal used shall be agreed upon between purchaser and manufacturer.

7.3.1 Supplementary Requirement S1 may be specified where 16-8-2 filler metal is required for joining thick sections of Types 316, 321, or 347 and has adequate corrosion resistance for the intended service.

8. Tensile Properties

8.1 The tensile properties of the fitting material shall conform to the requirements of Table 4. The testing and reporting shall be performed in accordance with Test Methods and Definitions A 370.

8.1.1 Specimens cut either longitudinally or transversely shall be acceptable for the tensile test.

8.1.2 While Table 4 specifies elongation requirements for both longitudinal and transverse specimens, it is not the intent that both requirements apply simultaneously. Instead, it is intended that only the elongation requirement that is appropriate for the specimen used be applicable.

8.2 Records of the tension test made on the starting material shall be certification that the material of the fitting meets the requirements of this specification provided that heat treatments are the same.

8.3 If the raw material was not tested, or if the heat treatment of the raw material was different than the heat treatment of the fitting, the fitting manufacturer shall perform at least one tension test per heat on material representative of the fitting, and in the same condition of heat treatment as the fitting it represents. Qualification of welding procedures shall be in accordance with 5.8.

8.4 If a tension test through the weld is desired, Supplementary Requirement S51 in Specification A 960/A 960M should be specified.

TABLE 4 Tensile Requirements

All WP and CR Grades	Yield Strength, min, ksi [MPa]	Tensile Strength, min, ksi [MPa]
304, 304LN, 304H, 309, 310S, 316, 316LN, 316H, 317, 317L, 321, 321H, 347, 347H, 348, 348H S31725	30 [205]	75 [515]
304L, 316L	25 [170]	70 [485]
304N, 316N, S31726	35 [240]	80 [550]
XM-19	55 [380]	100 [690]
S31254	44 [300]	94 [650] to 119 [820]
S33228	27 [185]	73 [500]
S34565	60 [415]	115 [795]
S38815	37 [255]	78 [540]

Elongation Requirements	Longitudinal	Transverse
Standard round specimen, or small proportional specimen, or strip-type specimen, minimum % in 4 D^A	28	20

^{A} S38815 Elongation in 2 in. — 30 % min.

9. Hydrostatic Tests

9.1 Hydrostatic testing is not required by this specification.

9.2 All Grade WP fittings shall be capable of withstanding without failure, leakage, or impairment of serviceability, a test pressure equal to that prescribed for the specified matching pipe or equivalent material.

9.3 All Grade CR fittings, except tees covered in 9.3.1, shall be capable of withstanding without failure, leakage, or impairment of serviceability, a test pressure based on the ratings in MSS SP-43.

9.3.1 Grade CR tees fabricated using intersection welds shall be capable of passing a hydrostatic test based on 70 % of the ratings in MSS SP-43.

10. Surface Quality

10.1 Fittings supplied under this specification shall be examined visually. Selected typical surface discontinuities shall be explored for depth. The fittings shall be free from surface discontinuities that penetrate more than 5 % of the specified nominal wall thickness, except as defined in 10.3 and 10.4, and shall have a workmanlike finish.

10.2 Surface discontinuities deeper than 5 % of the specified nominal wall thickness, except as defined in 10.3 and 10.4, shall be removed by the manufacturer by machining or grinding to sound metal, and the repaired areas shall be well faired. The wall thickness at all points shall be at least 87½ % of the specified nominal wall thickness, and the diameters at all points shall be within the specified limits.

10.3 Surface checks (fish scale) deeper than 1⁄64 in. [0.4 mm] shall be removed.

10.4 Mechanical marks deeper than 1⁄16 in. [1.6 mm] shall be removed.

10.5 When the removal of a surface discontinuity reduces the wall thickness below 87½ % of the specified nominal wall thickness at any point, the fitting shall be subject to rejection or to repair as provided in 10.6.

10.6 *Repair by Welding*:

10.6.1 Repair of unacceptable imperfections in the base metal is permissible for fittings made to the dimensional standards listed in 1.1 or for other standard fittings made for stock by the manufacturer. Prior approval of the purchaser is required to repair special fittings made to the purchaser's requirements. Welding of unacceptable imperfections in no case shall be permitted when the depth of defect exceeds 33⅓ % of the nominal wall thickness or the defect area exceeds 10 % of the surface area of the fitting.

10.6.2 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

10.6.3 The composition of the weld deposits shall be in accordance with 7.3 and in accordance with the procedure qualification for the applicable material.

10.6.4 Unacceptable imperfections shall be removed by mechanical means or by thermal cutting or gouging methods. Cavities prepared for welding shall be examined with liquid penetrant in accordance with Practice E 165. No cracks are permitted in the prepared cavities. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

10.6.5 The weld repair shall be permanently identified with the welder's stamp or symbol in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code.

10.6.6 Weld repair area(s) shall be blended uniformly to the base metal and shall be examined by liquid penetrant in accordance with Practice E 165. No cracks are permitted in the weld or surrounding ½ in. [12.7 mm] of base metal. Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

10.6.7 After weld repair, material shall be heat treated in accordance with Section 6.

10.7 The fittings shall be free of scale and shall be passivated.

11. Dimensions

11.1 For fittings covered by ASME B16.9, ASME B16.11, MSS SP-43, MSS SP-79, MSS SP-83, or MSS SP-95, the sizes, shapes, and dimensions of the fittings shall be as specified in those standards.

11.1.1 Fittings of size or shape differing from these standards, but meeting all other requirements of this specification, may be furnished in accordance with Supplementary Requirement S58 Specification A 960/A 960M.

12. Rejection and Rehearing

12.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the tests, the producer or supplier may make claim for rehearing.

12.2 Fittings that develop defects in shop working or application operations may be rejected. Upon rejection, the manufacturer shall be notified promptly in writing.

13. Test Reports

13.1 Test reports are required for all fittings covered by this specification. Each test report shall include the following information:

13.1.1 The year-date of the specification to which the fitting was furnished,

13.1.2 Heat number or serial number traceable to a heat number,

13.1.3 Chemical analyses for all starting materials,

13.1.4 Mechanical properties of all starting materials,

13.1.5 For construction with filler metal added, weld metal chemical analysis,

13.1.6 For welded fittings, construction method, weld process and procedure specification number,

13.1.7 Heat treatment type,

13.1.8 Results of all nondestructive examinations,

13.1.9 Results of all tests required by Supplementary Requirements and the order, and

13.1.10 Statement that the fitting was manufactured, sampled, tested and inspected in accordance with the specification and was found to meet the requirements.

14. Product Marking

14.1 All fittings shall have the prescribed information stamped or otherwise suitably marked on each fitting in accordance with the latest edition of MSS SP-25. See Table 5 for marking examples of grades and classes.

14.2 Marking paint or ink shall not contain harmful amounts of chlorides, metals, or metallic salt, such as zinc or copper, that cause corrosive attack on heating. On wall thicknesses thinner than 0.083 in. [2.1 mm], no metal impression stamps shall be used. Vibrating pencil marking is acceptable.

14.3 The prescribed information for butt-welding fittings shall be: the manufacturer's name or trademark (see Note 1), schedule number or nominal wall thickness designation, size, grade (see Table 2), class, and the heat number or manufacturer's heat identification. The class S marking need not be added to the material grade for threaded or socket-welded fittings.

14.4 The prescribed information for threaded or socket-welding fittings shall be: the manufacturer's name or trademark (see Note 1), pressure class or schedule number, grade (see Table 2) and class, and heat number or manufacturer's heat identification.

NOTE 1—For purposes of identification marking, the manufacturer is considered the organization that certifies that the piping component complies with this specification.

14.5 Fittings meeting the chemical and mechanical property requirements of Table 2 and Table 4 for more than one grade designation may be marked with more than one class or grade designation, such as WP304/304H; WP304/304L; WP304/304L/304N, WP316/316L, etc.

14.6 *Bar Coding*—In addition to the requirements in 14.1, 14.2, 14.3, 14.4, and 14.5, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

15. Keywords

15.1 austenitic stainless steel; corrosive service applications; pipe fittings; steel; piping applications; pressure containing parts; stainless steel fittings

TABLE 5 Product Marking Examples for Grades and Classes

Grade and Class Marking	Description
CR304	Single grade: No classes in CR grades
CR304/304L	Multiple grades, meet chemical and mechanical properties of each
WP304-S	Single Grade: seamless
WP304-W	Single Grade; welded : RT or UT pipe welds with filler metal and all fitting manufacturer's welds
WP304-WX	Single grade: welded: RT all welds with or without filler metal
WP304-WU	Single grade; welded: UT all welds with or without filler metal
WP304-304L-S	Multiple grades: meet chemical and mechanical properties of each: seamless

SUPPLEMENTARY REQUIREMENTS

One or more of the supplementary requirements described below or appearing in Specification A 960/A 960M may be included in the order or contract. When so included, a supplementary requirement shall have the same force as if it were in the body of the specification. Supplementary requirement details not fully described shall be agreed upon between the purchaser and the supplier.

S1. Special Filler Metal

S1.1 Filler metal shall be AWS Type E16-8-2 or ER 16-8-2 (AWS Specifications A 5.4 and A 5.9, respectively). Fittings welded with 16-8-2 weld metal shall be marked WP ___ HRW or CR ___ HRW, as appropriate.

S2. Stabilization Treatment

S2.1 Subsequent to the solution anneal required by 6.2, Grades 321, 321H, 347, 347H, 348, and 348H shall be given a stabilization heat treatment at 1500 to 1600 °F [815 to 870 °C] for a minimum of 2h/in. [4.7 min/mm] of thickness and then cooling in the furnace or in air. In addition to the marking required in Section 14, the grade designation symbol shall be followed by the symbol "S2."

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 403/A 403M – 06, that may impact the use of this specification. (Approved April 1, 2007)

(*1*) Added MSS SP-83 to Referenced Documents, 5.3, and 11.1.

(*2*) Added ASME B16.11 to 5.3.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 403/A 403M – 04, that may impact the use of this specification. (Approved March 1, 2006)

(*1*) Removed 310 and added 310S to "All WP and CR Grades" in Table 4.

Designation: A 381 – 96 (Reapproved 2005)

Standard Specification for Metal-Arc-Welded Steel Pipe for Use With High-Pressure Transmission Systems[1]

This standard is issued under the fixed designation A 381; 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 covers straight seam, double-submerged-arc-welded steel pipe (Note 1) suitable for high-pressure service, 16 in. (406 mm) and larger in outside diameter, with wall thicknesses from 5⁄16 to 1½ in. (7.9 to 38 mm). The pipe is intended for fabrication of fittings and accessories for compressor or pump-station piping. Pipe ordered to this specification shall be suitable for bending, flanging (vastoning), corrugating, and similar operations.

NOTE 1—A comprehensive listing of standardized pipe dimensions is contained in ANSI B36.10.

NOTE 2—The term "double welded" is commonly used in the gas and oil transmission industry, for which this pipe is primarily intended, to indicate welding with at least two weld passes, of which one is on the outside of the pipe and one on the inside. For some sizes of the pipe covered by this specification, it becomes expedient to use manual welding, in which case the provisions of Note 3 shall be followed.

1.2 Nine classes of pipe, based on minimum yield point requirements, are covered as indicated in Table 1.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 The following caveat applies to the test methods portion, Sections 9 and 10, only. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

TABLE 1 Tensile Requirements

Class	Yield Strength, min, psi (MPa)	Tensile Strength, min, psi (MPa)	Elongation in 2 in. (50.8 mm), min, %
Y 35	35 000 (240)	60 000 (415)	26
Y 42	42 000 (290)	60 000 (415)	25
Y 46	46 000 (316)	63 000 (435)	23
Y 48	48 000 (330)	62 000 (430)	21
Y 50	50 000 (345)	64 000 (440)	21
Y 52	52 000 (360)	66 000 (455)	20
Y 56	56 000 (385)	71 000 (490)	20
Y 60	60 000 (415)	75 000 (515)	20
Y 65	65 000 (450)	77 000 (535)	20

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[3]

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

Section VIII Pressure Vessels

Section IX Welding Qualifications

2.3 *ANSI Standard:*[5]

ANSI B36.10 Welded and Seamless Wrought Steel Pipe

3. Ordering Information

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

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

3.1.2 Name of material (metal-arc welded pipe),

3.1.3 Class (Table 1),

3.1.4 Material (carbon or alloy steel, Section 5),

3.1.5 Size (outside diameter and wall thickness),

3.1.6 Length (specific or random) (Section 13),

3.1.7 Ends (Section 14),

3.1.8 Heat treatment (stress-relieved or normalized) (see 5.6),

3.1.9 Optional requirements (see 5.2 (Note 3), Sections 11 and 15),

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Oct. 1, 2005. Published October 2005. Originally approved in 1954. Last previous edition approved in 2001 as A 381 – 96 (2001).

[2] 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.

[3] Withdrawn.

[4] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

3.1.10 Specification number, and

3.1.11 Special requirements or exceptions to this specification.

4. General Requirements

4.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M, unless otherwise provided herein.

5. Materials and Manufacture

5.1 The steel plate used in the manufacture of the pipe shall be of suitable welding quality carbon steel, or of suitable welding quality high-strength, low-alloy steel, as agreed upon between the manufacturer and purchaser.

5.2 The longitudinal edges of the plate shall be shaped to give the most satisfactory results by the particular welding process employed. The plate shall be properly formed and may be tacked preparatory to welding. The weld (except tack welds) shall be made preferably by the automatic submerged-arc-welding process (Note 3) and shall be of reasonably uniform width and height for the entire length of the pipe.

NOTE 3—By agreement between the manufacturer and the purchaser, manual welding by qualified welders using a qualified procedure may be used as an equal alternate to this specification.

5.3 Both longitudinal and circumferential (if any) joints shall be double welded, full penetration welds being made in accordance with procedures and by welders or welding operators qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX.

5.4 The contour of the reinforcement shall be smooth, with no valley or groove along the edge or in the center of the weld, and the deposited metal shall be fused smoothly and uniformly into the plate surface. The finish of the welded joint shall be reasonably smooth and free from irregularities, grooves, or depressions.

5.5 All pipe, after welding, shall be heat treated at a temperature of 1100°F (593°C) or higher.

5.6 When specified in the purchase order, all pipe after welding shall be heated at 1650 to 1750°F (899 to 954°C) and air cooled.

6. Chemical Composition

6.1 The carbon steels shall conform to the requirements as to chemical composition specified in Table 2.

6.2 The high-strength low-alloy steels shall be of specified chemical composition in order to ensure weldability and specified minimum tensile properties including elongation.

6.3 Mill test reports, as provided by the manufacturer of the plate, shall be furnished representing the chemical analysis of each heat of steel from which the plates are rolled. This chemical analysis shall conform to the requirements of 5.1, 6.1, or 6.2.

6.4 For referee purposes, Test Methods E 30 shall be used.

TABLE 2 Chemical Requirements for Carbon Steels on Product Analysis

Element	Composition, %, max	
	Ladle	Check
Carbon	0.26	0.30
Manganese	1.40	1.50
Phosphorus	0.025	0.030
Sulfur	0.025	0.025

7. Tensile Requirements

7.1 The tensile properties of transverse body-test specimens taken from the finished pipe shall conform to the requirements prescribed in Table 1. The tensile strength of the transverse weld-test specimens shall conform to that specified in Table 1.

7.2 Transverse body-test specimens shall be taken approximately opposite the weld; transverse weld-test specimens shall be taken with the weld at the center of the specimen. For pipe wall thicknesses up to ¾ in. (19 mm), incl, all transverse test specimens shall be approximately 1½ in. (38 mm) wide in the gauge length and shall represent the full wall thickness of the pipe from which the specimen was cut (see Fig. 23, Test Methods and Definitions A 370). For pipe with wall thicknesses over ¾ in. (19 mm), the standard 0.505-in. (12.83-mm) round tension test specimen with 2-in. (50.8-mm) gauge length shall be used (see Fig. 5, Test Methods and Definitions A 370).

7.3 If the tension test specimen from any lot of pipe fails to conform to the requirements for the particular grade of pipe ordered, the manufacturer may elect to make retests on two additional lengths of pipe from the same lot, each of which shall conform to the requirements prescribed in Table 2. If one or both of the retests fail to conform to the requirements, the manufacturer may elect to test each of the remaining lengths of pipe in the lot. Retests are required only for the particular test with which the pipe specimen did not comply originally.

7.4 All test specimens which are flattened cold may be reheat treated before machining.

8. Transverse Guided-Bend Tests Weld

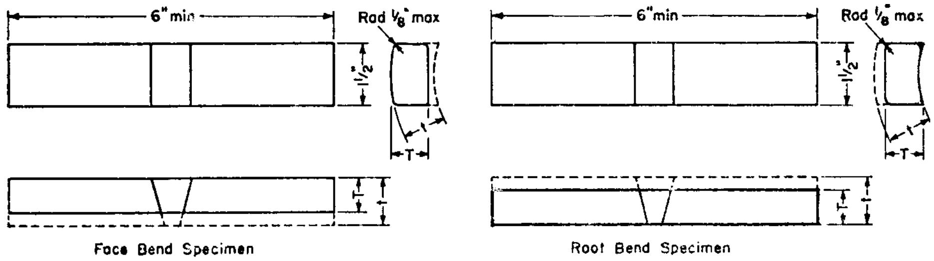
8.1 Transverse weld test specimens shall be subject to face and root guided-bend tests. The specimens shall be approximately 1½ in. (38.1 mm) wide, at least 6 in. (152 mm) in length with the weld at the center, and shall be machined in accordance with Fig. 1. One specimen shall be bent with the inside surface of the pipe against the plunger, and the other specimen with the outside surface against the plunger. The dimensions of the plunger for the bending jig shall be in accordance with Fig. 2 and the other dimensions shall be substantially as shown in Fig. 2.

8.2 The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. (3.17 mm) in any direction are present in the weld metal or between the weld and pipe metal after bending. Cracks which originate along the edges of the specimen during testing, and that are less than ¼ in. (6.35 mm), measured in any direction, shall not be considered.

9. Hydrostatic Test

9.1 Each length of pipe with wall thickness of ½ in. (12.7 mm) and less shall be tested to a hydrostatic pressure which will produce in the pipe wall a stress of not less than 85 % of the minimum specified yield point. This pressure shall be determined by the following equation:

$$P = 2St/D$$



Metric Equivalents

in.	1⁄8	1 1⁄2	6
mm	3.2	38.1	152

Pipe Wall Thickness (*t*), in. (mm)	Test Specimen Thickness, in. (mm)
Up to 3⁄8 (9.5), incl	*t*
Over 3⁄8 (9.5)	3⁄8 (9.5)

FIG. 1 Transverse Face- and Root-Bend Test Specimens

where:

P = hydrostatic test pressure, psi,
S = 85 % of the specified minimum yield strength of Table 1,
t = specified wall thickness, in., and
D = specified outside diameter, in.

9.2 Each length of pipe with a wall thickness over ½ in. (12.7 mm) shall be tested to a hydrostatic pressure calculated as in 9.1 except that the stress S shall be 70 % of the specified yield point, and that a 3000-psi (20.6-MPa) maximum test pressure shall apply.

9.3 When specified in the order, pipe may be furnished without hydrostatic testing, and each length so furnished shall include with the mandatory marking the letters "NH."

9.4 When certification is required by the purchaser and the hydrostatic test has been omitted, the certification shall clearly state "Not Hydrostatically Tested," and the specification number and class, as shown on the certification, shall be followed by the letters "NH."

10. Mechanical Tests Required

10.1 *Transverse Body Tension Test*—One test shall be made on one length of pipe from each lot of 100 lengths or less, of each size and heat, to determine the yield strength, tensile strength, and percent of elongation in 2 in. (50.8 mm).

10.2 *Transverse Weld Tension Test*—One test shall be made on one length of pipe from each lot of 100 lengths or less, of each size, for tensile strength only.

10.3 *Transverse Guided-Bend Weld Test:*

10.3.1 Two weld bend test specimens as described in 8.1 shall be cut from a length of pipe from each lot of 50 lengths or less, of each size. Bend test specimens shall be cut from pipe ends which have not been repaired.

10.3.2 If either test fails to conform to specified requirements, the manufacturer may elect to make retests on two additional lengths of pipe from the same lot, each of which shall conform to the requirements specified in 8.2. If any of the retests fail to conform to the requirements, the manufacturer may elect to test each of the remaining lengths of pipe in the lot.

10.4 *Hydrostatic Test*—Each length of pipe shall be subjected to the hydrostatic test.

11. Radiographic Examination

11.1 The manufacturer shall employ radiography as a production control on the welding employed in the manufacture of pipe to this specification. At least 5 % of the total linear footage of welding shall be subjected to radiographic examination to ensure that the welding equipment is consistently producing the required quality. The selection of the sections to be so examined shall be at the discretion of the manufacturer's inspector. The purchaser's inspector shall have access to the radiographic films and records of current production.

11.2 When so specified on the purchase order, all welding performed under these specifications shall be fully radiographed. The procedures and requirements shall conform to Paragraph UW-51 of the ASME Boiler and Pressure Vessel Code, Section VIII (latest edition).

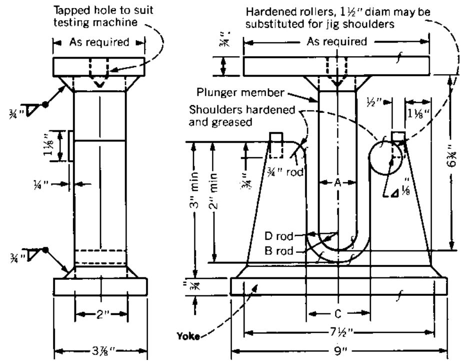
12. Permissible Variations in Dimensions

12.1 Permissible variations in dimensions shall not exceed the following:

12.1.1 *Outside Diameter*—±0.5 % of the specified outside diameter for the outside diameter based on circumferential measurement, except that in sizes 24 in. (610 mm) and smaller this tolerance shall be ±1⁄8 in. (3.2 mm).

12.1.2 *Out-of-Roundness*—1 %, that is, the difference between the major and minor outside diameter.

12.1.3 *Thickness*—The minimum wall thickness shall not be more than 0.01 in. (0.25 mm) under the specified thickness. Localized (isolated and noncontinuous) reductions in wall thickness caused by noninjurious surface defects may be permitted up to a depth not exceeding 6½ % the specified pipe wall thickness.



Metric Equivalents

in.	mm	in.	mm	in.	mm
1⁄16	1.6	1 11⁄16	42.9	3 1⁄8	79.4
1⁄8	3.2	1 3⁄4	44.4	3 3⁄8	85.7
1⁄4	6.4	1 7⁄8	47.6	3 1⁄2	88.9
3⁄8	9.5	1 15⁄16	49.2	3 3⁄4	95.2
1⁄2	12.7	2	50.8	3 7⁄8	98.4
3⁄4	19.0	2 1⁄8	54.0	4 1⁄4	108.0
15⁄16	23.8	2 1⁄4	57.2	4 5⁄8	117.4
1 1⁄8	28.6	2 5⁄16	58.7	5 1⁄2	139.7
1 5⁄16	33.3	2 5⁄8	66.6	6 3⁄4	171.4
1 3⁄8	34.9	2 3⁄4	69.8	7 1⁄2	190.5
1 1⁄2	38.1	3	76.2	9	228.6
1 9⁄16	39.7				

Class of Steel	Y35		Y42		Y46		Y48, Y50, and Y52		Y56 and Y60		Y65	
Thickness of Specimen, in.	3⁄8	*t*	3⁄8	*t*	3⁄8	*t*	3⁄8	*t*	3⁄8	*t*	3⁄8	*t*
"A" dimension	1 7⁄8	5*t*	2 1⁄4	6*t*	2 5⁄8	7*t*	3	8*t*	3 3⁄8	9*t*	3 3⁄4	10*t*
"B" dimension	15⁄15	(*tt*/2)	1 1⁄8	3*t*	1 5⁄16	(7*t*/2)	1 1⁄2	4*t*	1 11⁄16	(9*t*/2)	1 7⁄8	5*t*
"C" dimension	2 3⁄4	7*t* + 1⁄8	3 1⁄8	8*t* + 1⁄8	3 1⁄2	9*t* + 1⁄8	3 7⁄8	10*t* + 1⁄8	4 1⁄4	11*t* + 1⁄8	4 5⁄8	12*t* + 1⁄8
"D" dimension	1 3⁄8	(7*t*/2) + 1⁄16	1 9⁄16	4*t* + 1⁄16	1 3⁄4	(9*t*/2) + 1⁄16	1 15⁄16	5*t* + 1⁄16	2 1⁄8	5 1⁄2 + 1⁄16	2 5⁄16	6*t* + 1⁄16

NOTE 1—"*t*'' equals wall thickness of pipe.

NOTE 2—The dimensions in the above table are based on the following ratio of diameter of bend to thickness of specimen:

Class	Ratio
Y35	5
Y42	6
Y46	7
Y48, Y50, and Y52	8
Y56 and Y60	9
Y65	10

FIG. 2 Guided Bend Test Jig

13. Lengths

13.1 Unless otherwise specified, pipe shall be furnished in approximately 20-ft (6.1-m) lengths.

13.2 Where longer lengths are required, circumferentially welded joints shall be permitted.

13.3 Shorter lengths, when required, shall be specified in the order.

14. Ends

14.1 Pipe ends shall be furnished beveled as specified in the order. The width of the end shall be 1⁄16 in. (1.6 mm) with a tolerance of ±1⁄32 in. (0.8 mm).

14.2 The end of the pipe shall not be out of square more than 1⁄16 in. (1.6 mm).

15. Workmanship, Finish, and Appearance

15.1 The finished pipe shall be free of injurious defects and shall have a workmanlike finish.

15.2 *Repair of Plate Defects by Machining or Grinding*—Pipe showing moderate slivers may be machined or ground inside or outside to a depth which shall ensure the removal of all included scale and slivers, providing the wall thickness is not reduced below the specified minimum wall thickness.

15.3 *Repair of Plate Defects by Welding*—Repair of plate defects by welding shall be permitted. Welding of injurious defects shall not be permitted when the depth of defect exceeds 33 1⁄3 % of the specified pipe wall thickness or the length of repair exceeds 25 % of the specified diameter of the pipe.

Defects must be thoroughly removed and the welding performed by a welder qualified in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section IX. Such repair welding shall be ground or machined flush with the surface of the pipe. All repair welding shall be done before final heat treatment.

16. Coating

16.1 Unless otherwise specified in the purchase order, the pipe shall be furnished uncoated.

17. Inspection

17.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. All reasonable facilities shall be afforded the inspector, to satisfy him that the material is being furnished in accordance with this specification. All tests called for by this specification and inspection shall be made at the place of manufacture prior to shipment unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

18. Product Marking

18.1 In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include the hydrostatic test pressure. Marking shall be by stenciling along the welded seam.

18.2 *Bar Coding*—In addition to the requirements in 18.1, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

19. Keywords

19.1 arc welded steel pipe; steel pipe

Standard Specification for Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service[1]

This standard is issued under the fixed designation A 376/A 376M; 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 seamless austenitic steel pipe intended for high-temperature central-station service. Among the grades covered are five H grades and two nitrogen grades (304N and 316N) that are specifically intended for high-temperature service.

1.2 Optional supplementary requirements (S1 through S10) are provided. These supplementary requirements specify additional tests that will be made only when stated in the order, together with the number of such tests required.

1.3 Grades TP321 and TP321H have lower strength requirements for nominal wall thicknesses greater than ⅜ in. [9.5 mm].

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 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]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

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

E 112 Test Methods for Determining Average Grain Size

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

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

E 426 Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys

2.2 *Other Standards:*

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing[4]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A 941.

4. Ordering Information

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

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

4.1.2 Name of material (seamless austenitic steel pipe),

4.1.3 Grade (Table 1),

4.1.4 Size (nominal size, or outside diameter and schedule number or average wall thickness),

4.1.5 Lengths (specific or random), (Permissible Variations in Length Section of Specification A 999/A 999M),

4.1.6 End finish (Ends Section of Specification A 999/A 999M),

4.1.7 Optional requirements (Section 9) (see Hydrostatic Test Requirements Section and the Permissible Variation in Weight for Seamless Pipe Section for weighing individual lengths, of Specification A 999/A 999M), (see 10.6, repairing by welding; 14.3, die stamping),

4.1.8 Test report required (Certification Section of Specification A 999/A 999M),

4.1.9 Specification designation, and

4.1.10 Special requirements or any supplementary requirements selected, or both.

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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.

Current edition approved March 1, 2006. Published April 2006. Originally approved in 1954. Last previous edition approved in 2004 as A 376/A 376M – 04.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-376 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 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	Composition,%												
		Carbon	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Titanium	Columbium	Tantalum	Nitrogen[A]	Others
TP304	S30400	0.08 max	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	. . .	. . .
TP304N	S30451	0.08 max	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .
TP304LN	S30453	0.035 max	2.00	0.045	0.030	0.75	8.0–11.0	18.0–20.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .
TP316	S31600	0.08 max	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .
TP316N	S31651	0.08 max	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	0.10–0.16	. . .
TP316LN	S31653	0.035 max	2.00	0.045	0.030	0.75	11.0–14.0	16.0–18.0	2.00–3.00	. . .	. . .	. . .	0.10–0.16	. . .
TP321	S32100	0.08 max	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	. . .	[B]	. . .	. . .	. . .	. . .
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	. . .	[C]	. . .	. . .	. . .	. . .
TP347	S34700	0.08 max	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	. . .	. . .	[D]	. . .	. . .	. . .
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	. . .	. . .	[E]	. . .	. . .	. . .
TP348[F]	S34800	0.08 max	2.00	0.045	0.030	0.75	9.0–13.0	17.0–19.0	. . .	. . .	[D]	0.10	. . .	Co 0.20 max
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	9.0–13.0	17.0–19.0			[E]	0.10		
16-8-2H	S16800	0.05–0.10	2.00	0.045	0.030	0.75	7.5–9.5	14.5–16.5	1.50–2.00	. . .	. . .	. . .	. . .	. . .
. . .	S31725	0.030 max	2.00	0.045	0.030	0.75	13.5–17.5	18.0–20.0	4.0–5.0	. . .	. . .	. . .	0.20 max	Cu 0.75 max
. . .	S31726	0.030 max	2.00	0.045	0.030	0.75	14.5–17.5	17.0–20.0	4.0–5.0	. . .	. . .	. . .	0.10–0.20	Cu 0.75 max
. . .	S34565	0.030 max	5.0–7.0	0.030	0.010	1.0	16.0–18.0	23.0–25.0	4.0–5.0	. . .	. . .	. . .	0.040–0.060	Cb 0.10 max

[A] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
[B] The titanium content shall be not less than five times the carbon content and not more than 0.70 %.
[C] The titanium content shall be not less than four times the carbon content and not more than 0.70 %.
[D] The columbium content shall be not less than ten times the carbon content and not more than 1.10 %.
[E] The columbium content shall be not less than eight times the carbon content and not more than 1.10 %.
[F] This grade is intended for special purpose applications.

5. General Requirements

5.1 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.

6. Materials and Manufacture

6.1 *Manufacture*—At the manufacturer's option, pipe may be either hot finished or cold finished, with a suitable finishing treatment, where necessary.

6.2 *Heat Treatment*:

6.2.1 All pipe shall be furnished in the heat-treated condition unless the order specifically states that no final heat treatment shall be applied. When the order is furnished without final heat treatment, each pipe shall be stenciled "HT-O."

6.2.2 As an alternate to final heat treatment in a continuous furnace or batch-type furnace, immediately following hot forming while the temperature of the pipes is not less than the specified minimum solution treatment temperature, pipes may be individually quenched in water or rapidly cooled by other means.

6.2.3 *Grades TP304, TP304N, TP304LN, TP316, TP316N, TP316LN, TP321, TP347, TP348, 16-8-2H, S 31725, and S 31726* —Unless otherwise stated in the order, heat treatment shall consist of heating to a minimum temperature of 1900 °F [1040 °C] and quenching in water or rapidly cooling by other means.

6.2.3.1 The purchaser may specify controlled structural or special service characteristics which shall be used as a guide for the most suitable heat treatment. If the final heat treatment is at a temperature under 1900 °F [1040 °C], each pipe shall be stenciled with the final heat treatment temperature in degrees Fahrenheit or Celsius after the suffix "HT."

6.2.4 *Grades TP304H, TP316H, TP321H, TP347H, TP348H, and 16-8-2H*—If cold working is involved in processing, the minimum solution-treating temperature for Grades TP321H, TP347H, and TP348H shall be 2000 °F [1100 °C], for Grades TP304H and TP316H, 1900 °F [1040 °C], and for Grade 16-8-2H, 1800 °F [980 °C]. If the material is hot-rolled, the minimum solution-treating temperatures for Grades TP321H, TP347H, and TP348H shall be 1925 °F [1050 °C], for Grades TP304H and TP316H, 1900 °F [1040 °C], and for Grade 16-8-2H, 1800 °F [980 °C].

6.2.5 *Grade S34565*—Heat treatment shall consist of heating to a temperature in the range of 2050 °F [1120 °C] minimum and 2140 °F [1170 °C] maximum, and quenching in water or rapidly cooling by other means.

6.3 A solution annealing temperature above 1950 °F [1065 °C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP321, TP321H, TP347, TP347H, TP348, and TP348H. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S9).

6.4 The grain size of grades 304H, 316H, 321H, 347H, and 348H as determined in accordance with Test Methods E 112, shall be No. 7 or coarser.

7. Chemical Composition

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

8. Product Analysis

8.1 At the request of the purchaser, an analysis of one billet from each heat or two pipes from each lot (Note 2) shall be made by the manufacturer. A lot of pipe shall consist of the following:

NPS Designator	Lengths of Pipe in Lot
Under NPS 2	400 or fraction thereof
NPS 2 to NPS 5, incl	200 or fraction thereof
Over NPS 5	100 or fraction thereof

NOTE 2—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 If the analysis of one of the tests specified in Section 9 does not conform to the requirements specified in Section 7, 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 Requirements

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

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 assure 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 10.6.

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

10.2.4 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 (see Note 3), and pits, any of which imperfections are deeper than 1⁄16 in. [1.6 mm].

NOTE 3—Marks and abrasions are defined as cable marks, dinges, guide marks, roll marks, ball scratches, scores, die marks, and so forth.

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 A 999/A 999M.

10.7 The finished pipe shall be reasonably straight.

10.8 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser may request that a passivating treatment be applied.

TABLE 2 Tensile Requirements

Grade	Tensile[A] strength, min, ksi [MPa]	Yield strength min, ksi [MPa]	Elongation in 2 in. or 50 mm (or 4D) min, %	
			Longitudinal	Transverse
TP304, TP304H, TP304LN, TP316, TP316H, TP316LN, TP347, TP347H, TP348, TP348H, 16-8-2H, S31725	75 [515]	30 [205]	35	25
TP304N, TP316N, S31726	80 [550]	35 [240]	35	25
S34565	115 [790]	60 [415]	35	30
TP321, 321H				
≤3⁄8 ″	75 [515]	30 [205]	35	25
>3⁄8 ″[B]	70 [480]	25 [170]	35	25

[A] For grade TP304, NPS8 or larger, and in schedules 140 and heavier, the required minimum tensile strength shall be 70 ksi [480 MPa].
[B] Prior to the issuance of A 376/A 376M – 88, the tensile and yield strength values were 75 [520] and 30 [210] respectively, for nominal wall greater than 3⁄8 in. [9.5 mm].

11. Hydrostatic or Nondestructive Electric Test

11.1 Each pipe shall be subjected to the Nondestructive Electric Test or the Hydrostatic Test. Unless specified by the purchaser, either test may be used at the option of the producer.

11.2 *Hydrostatic Test*— Each length of finished pipe shall be subjected to the hydrostatic test in accordance with Specification A 999/A 999M, unless specifically exempted under the provisions of 11.3 and 11.4.

11.3 For pipe sizes NPS 24 and over, the purchaser, with the agreement of the manufacturer, may complete the hydrostatic test requirement with the system pressure test, which may be lower or higher than the specification test pressure, but in no case shall the test pressure be lower than the system design pressure. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory marking the letters "NH."

11.4 *Nondestructive Examination*—Each pipe shall be examined with a nondestructive test in accordance with Practice E 213 or Practice E 426. Unless specifically called out by the purchaser, the selection of the nondestructive electric test will be at the option of the manufacturer. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

11.4.1 The following information is for the benefit of the user of this specification:

11.4.1.1 The reference standards defined in 11.10.1 through 11.10.4 are convenient standards for calibration of nondestructive testing equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

11.4.1.2 The ultrasonic testing (UT) can be performed to detect both longitudinally and circumferentially oriented defects. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep, defects.

11.4.1.3 The eddy-current testing (ET) referenced in Practice E 426 has the capability of detecting significant discontinuities, especially the short abrupt type.

11.4.1.4 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

11.5 *Time of Examination*—Nondestructive testing for specification acceptance shall be performed after all mechanical processing, heat treatments, and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

11.6 *Surface Condition*:

11.6.1 All surfaces shall be free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

11.6.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test.

11.7 *Extent of Examination*:

11.7.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except as in 6.2.

11.7.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

11.8 *Operator Qualifications*—The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent recognized and documented standard.

11.9 *Test Conditions*:

11.9.1 For eddy-current testing, the excitation coil frequency shall be chosen to ensure adequate penetration yet provide good signal-to-noise ratio.

11.9.2 The maximum eddy-current coil frequency used shall be as follows:

On specified walls up to 0.050 in.—100 KHz max
On specified walls up to 0.150 in.—50 KHz max
On specified walls up to 0.150 in.—10 KHz max

11.9.3 *Ultrasonic*—For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.00 MHz and the maximum nominal transducer size shall be 1.5 in.

11.9.3.1 If the equipment contains a reject notice filter setting, this shall remain off during calibration and testing unless linearity can be demonstrated at that setting.

11.10 *Reference Standards*:

11.10.1 Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS, or outside diameter and schedule or wall thickness), surface finish, and heat treatment condition as the pipe to be examined.

11.10.2 *For Ultrasonic Testing*, the reference ID and OD notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of each notch shall not exceed 12½ % of the specified nominal wall thickness of the pipe or 0.004 in., whichever is greater. The width of the notch shall not exceed twice the depth. Notches shall be placed on both the OD and ID surfaces.

11.10.3 *For Eddy-Current Testing*, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

11.10.3.1 *Drilled Hole*—The reference standard shall contain three or more holes, equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. One hole shall be drilled in the weld, if visible. Alternately, the producer of welded pipe may choose to drill one hole in the weld and run the calibration standard through the test coils three times with the weld turned at 120° on each pass. The hole diameter shall vary with NPS as follows:

NPS Designator	Hole Diameter
	0.039 in. (1 mm)
above ½ to 1¼	0.055 in. (1.4 mm)
above 1¼ to 2	0.071 in. (1.8 mm)
above 2 to 5	0.087 in. (2.2 mm)
above 5	0.106 in. (2.7 mm)

11.10.3.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼-in. (6.4-mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding 12½ % of the specified nominal wall thickness of the pipe or 0.004 in. (0.102 mm), whichever is greater.

11.10.3.3 *Longitudinal Notch*—A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12½ % of the specified wall thickness of the pipe or 0.004 in., whichever is greater. The length of the notch shall be compatible with the testing method.

11.10.3.4 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

11.11 *Standardization Procedure*:

11.11.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h. More frequent standardization may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

11.11.2 The test apparatus shall also be standardized after any change in test system settings; change of operator; equipment repair; or interruption due to power loss, process shutdown, or when a problem is suspected.

11.11.3 The reference standard shall be passed through the test apparatus at the same speed and test system settings as the pipe to be tested.

11.11.4 The signal-to-noise ratio for the reference standard shall be 2½ to 1 or greater. Extraneous signals caused by identifiable causes such as dings, scratches, dents, straightener marks, and so forth, shall not be considered noise. The rejection amplitude shall be adjusted to be at least 50 % of full scale of the readout display.

11.11.5 If upon any standardization, the rejection amplitude has decreased by 29 % (3 dB) of peak height from the last standardization, the pipe since the last calibration shall be rejected. The test system settings may be changed, or the transducer(s), coil(s) or sensor(s) adjusted, and the unit restandardized, but all pipe tested since the last acceptable standardization must be retested for acceptance.

11.12 *Evaluation of Imperfections*:

11.12.1 Pipes producing a signal equal to or greater than the lowest signal produced by the reference standard(s) shall be identified and separated from the acceptable pipes. The area producing the signal may be reexamined.

11.12.2 Such pipes shall be rejected if the test signal was produced by imperfections that cannot be identified or was produced by cracks or crack-like imperfections. These pipes may be repaired in accordance with Sections 13 and 14. To be accepted, a repaired pipe must pass the same nondestructive test by which it was rejected, and it must meet the minimum wall thickness requirements of this specification.

11.12.3 If the test signals were produced by visual imperfections such as:

(1) Scratches,
(2) Surface roughness,
(3) Dings,
(4) Straightener marks,
(5) Cutting chips,
(6) Steel die stamps,
(7) Stop marks, or
(8) Pipe reducer ripple.

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).

11.12.4 Rejected pipe may be reconditioned and retested providing the wall thickness is not decreased to less than that required by this or the product specification. The outside diameter at the point of grinding may be reduced by the amount so removed. To be accepted, retested pipe shall meet the test requirement.

11.12.5 If the imperfection is explored to the extent that it can be identified as non-rejectable, the pipe may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness.

12. Mechanical Tests Required

12.1 *Transverse or Longitudinal Tension Test*—The tension test shall be performed on 1 % of the pipe from each lot.

NOTE 4—The term "lot" applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace or by directly obtaining the heat treated condition by quenching after hot forming. When final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge.

12.2 *Flattening Test*—For pipe heat treated in a batch-type furnace, the flattening test shall be made on 5 % of the pipe from each heat-treated lot (see Note 4). When heat treated by the continuous process or when treated condition is obtained directly by quenching after hot forming, this test shall be made on a sufficient number of pipe to constitute 5 % of the lot (Note 4) but in no case less than two pipes.

13. Certification

13.1 In addition to the certification required by Specification A 999/A 999M, the certification for pipe furnished to this specification shall identify each length of pipe which is furnished without the manufacturer's completed hydrostatic test, in accordance with 11.3.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 999/A 999M, the marking shall include the ANSI schedule number, the heat number or manufacturer's number by which the heat can be identified, the marking requirements of 6.2, and, if applicable, NH when hydrotesting is not performed and ET when eddy-current testing is performed, or UT when ultrasonic testing is performed.

14.2 If the pipe conforms to any of the supplementary requirements specified in S1 through S10, compliance shall be so indicated by adding the symbol "S" directly followed by the number of the applicable supplementary requirement to the marking prescribed in 14.1.

14.3 No steel indentation stamping shall be done without the purchaser's consent.

15. Keywords

15.1 austenitic stainless steel; feedwater heater tubes; stainless steel tube; steel tube; welded steel tube

SUPPLEMENTARY REQUIREMENTSFOR PIPE REQUIRING SPECIAL CONSIDERATION

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Tests

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 and over in nominal diameter. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Photomicrographs

S5.1 Photomicrographs at 100 diameters may be made from one end of each piece of pipe furnished in sizes 6 in. [152 mm] and larger in the as-furnished condition. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, piece number, and heat. Such photomicrographs are for information only, and shall show the actual metal structure of the pipe as finished.

S6. Ultrasonic Test

S6.1 Each piece of pipe may be ultrasonically tested to determine its soundness throughout the entire length of the pipe. Each piece shall be ultrasonically tested in a circumferential direction in such a manner that the entire piece is scanned by the ultrasonic beam. The calibration standard shall be prepared from a section of pipe which has two notches, one in the inside surface and one in the outside surface. The notches shall be at least 1½-in. [38-mm] long and have a depth of 3 % of the wall thickness, or 0.004 in. [0.1 mm], whichever is the greater. Any pipe showing an ultrasonic indication of greater amplitude than the amplitude of the indication from the calibration standard shall be subject to rejection.

S7. Hot Ductility Test for Indicating Weldability

S7.1 A high-temperature ductility test may be made upon each heat of material supplied in heavy-wall pipe sections. An appropriate specimen shall be heated to an initial temperature, cooled 100 °F [50 °C], then subjected to a tension test, and shall show a minimum reduction of area of 60 %. The initial temperature is that temperature 50 °F [30 °C] below the temperature at which material exhibits zero ductility. Rejection of material shall not be based upon this test.

S8. Retests

S8.1 Upon the purchaser's request, retests shall be made from sections of material removed from any part of the pipe. Failure to meet the requirements stated in this specification shall be cause for rejection.

S9. Stabilization Heat Treatment

S9.1 Subsequent to the solution anneal required in 6.4, Grades TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S10. Intergranular Corrosion Test

S10.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S10.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S10.2 A stabilization heat treatment in accordance with Supplementary Requirement S9 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 376/A 376M - 04, that may impact the use of this specification. (Approved March 1, 2006)

(*1*) Added grade TP348H.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 376/A 376M - 02a, that may impact the use of this specification. (Approved October 1, 2004)

(*1*) Modified paragraph 14.1 to remove hydrotest pressure and length from the product marking requirements.

Designation: A 370 – 07a

Standard Test Methods and Definitions for Mechanical Testing of Steel Products[1]

This standard is issued under the fixed designation A 370; 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*

1.1 These test methods[2] cover procedures and definitions for the mechanical testing of wrought and cast steels, stainless steels, and related alloys. The various mechanical tests herein described are used to determine properties required in the product specifications. Variations in testing methods are to be avoided, and standard methods of testing are to be followed to obtain reproducible and comparable results. In those cases in which the testing requirements for certain products are unique or at variance with these general procedures, the product specification testing requirements shall control.

1.2 The following mechanical tests are described:

	Sections
Tension	5 to 13
Bend	14
Hardness	15
Brinell	16
Rockwell	17
Portable	18
Impact	19 to 28
Keywords	29

1.3 Annexes covering details peculiar to certain products are appended to these test methods as follows:

	Annex
Bar Products	A1.1
Tubular Products	Annex A2
Fasteners	Annex A3
Round Wire Products	Annex A4
Significance of Notched-Bar Impact Testing	Annex A5
Converting Percentage Elongation of Round Specimens to Equivalents for Flat Specimens	Annex A6
Testing Multi-Wire Strand	Annex A7
Rounding of Test Data	Annex A8
Methods for Testing Steel Reinforcing Bars	Annex A9
Procedure for Use and Control of Heat-Cycle Simulation	Annex A10

1.4 The values stated in inch-pound units are to be regarded as the standard.

1.5 When this document is referenced in a metric product specification, the yield and tensile values may be determined in inch-pound (ksi) units then converted into SI (MPa) units. The elongation determined in inch-pound gauge lengths of 2 or 8 in. may be reported in SI unit gauge lengths of 50 or 200 mm, respectively, as applicable. Conversely, when this document is referenced in an inch-pound product specification, the yield and tensile values may be determined in SI units then converted into inch-pound units. The elongation determined in SI unit gauge lengths of 50 or 200 mm may be reported in inch-pound gauge lengths of 2 or 8 in., respectively, as applicable.

1.6 Attention is directed to Practices A 880 and E 1595 when there may be a need for information on criteria for evaluation of testing laboratories.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 703/A 703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use

A 833 Practice for Indentation Hardness of Metallic Materials by Comparison Hardness Testers

A 880 Practice for Criteria for Use in Evaluation of Testing Laboratories and Organizations for Examination and Inspection of Steel, Stainless Steel, and Related Alloys[4]

E 4 Practices for Force Verification of Testing Machines

E 6 Terminology Relating to Methods of Mechanical Testing

E 8 Test Methods for Tension Testing of Metallic Materials

E 8M Test Methods for Tension Testing of Metallic Materials [Metric]

E 10 Test Method for Brinell Hardness of Metallic Materials

[1] These test methods and definitions are under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and are the direct responsibility of Subcommittee A01.13 on Mechanical and Chemical Testing and Processing Methods of Steel Products and Processes.

Current edition approved June 1, 2007. Published June 2007. Originally approved in 1953. Last previous edition approved in 2007 as A 370 – 07.

[2] For *ASME Boiler and Pressure Vessel Code* applications see related Specification SA-370 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] Withdrawn.

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

E 18 Test Methods for Rockwell Hardness of Metallic Materials
E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 83 Practice for Verification and Classification of Extensometer Systems
E 110 Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers
E 190 Test Method for Guided Bend Test for Ductility of Welds
E 290 Test Methods for Bend Testing of Material for Ductility
E 1595 Practice for Evaluating the Performance of Mechanical Testing Laboratories[4]

2.2 *ASME Document:*[5]

ASME Boiler and Pressure Vessel Code, Section VIII, Division I, Part UG-8

3. General Precautions

3.1 Certain methods of fabrication, such as bending, forming, and welding, or operations involving heating, may affect the properties of the material under test. Therefore, the product specifications cover the stage of manufacture at which mechanical testing is to be performed. The properties shown by testing prior to fabrication may not necessarily be representative of the product after it has been completely fabricated.

3.2 Improper machining or preparation of test specimens may give erroneous results. Care should be exercised to assure good workmanship in machining. Improperly machined specimens should be discarded and other specimens substituted.

3.3 Flaws in the specimen may also affect results. If any test specimen develops flaws, the retest provision of the applicable product specification shall govern.

3.4 If any test specimen fails because of mechanical reasons such as failure of testing equipment or improper specimen preparation, it may be discarded and another specimen taken.

4. Orientation of Test Specimens

4.1 The terms "longitudinal test" and "transverse test" are used only in material specifications for wrought products and are not applicable to castings. When such reference is made to a test coupon or test specimen, the following definitions apply:

4.1.1 *Longitudinal Test*, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is parallel to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a longitudinal tension test specimen is in the direction of the greatest extension, and the axis of the fold of a longitudinal bend test specimen is at right angles to the direction of greatest extension (Fig. 1, Fig. 2a, and 2b).

4.1.2 *Transverse Test*, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is at right angles to the direction of the greatest extension of the steel during rolling or forging. The stress applied to a transverse tension test specimen is at right angles to the greatest extension, and the axis of the fold of a transverse bend test specimen is parallel to the greatest extension (Fig. 1).

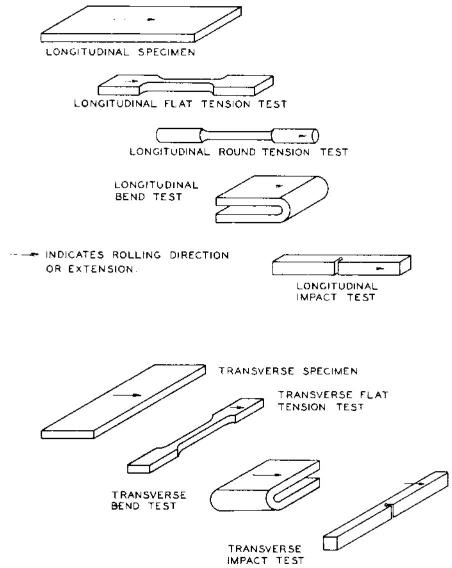


FIG. 1 The Relation of Test Coupons and Test Specimens to Rolling Direction or Extension (Applicable to General Wrought Products)

4.2 The terms "radial test" and "tangential test" are used in material specifications for some wrought circular products and are not applicable to castings. When such reference is made to a test coupon or test specimen, the following definitions apply:

4.2.1 *Radial Test*, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to the axis of the product and coincident with one of the radii of a circle drawn with a point on the axis of the product as a center (Fig. 2a).

4.2.2 *Tangential Test*, unless specifically defined otherwise, signifies that the lengthwise axis of the specimen is perpendicular to a plane containing the axis of the product and tangent to a circle drawn with a point on the axis of the product as a center (Fig. 2a, 2b, 2c, and 2d).

TENSION TEST

5. Description

5.1 The tension test related to the mechanical testing of steel products subjects a machined or full-section specimen of the material under examination to a measured load sufficient to cause rupture. The resulting properties sought are defined in Terminology E 6.

5.2 In general, the testing equipment and methods are given in Test Methods E 8. However, there are certain exceptions to Test Methods E 8 practices in the testing of steel, and these are covered in these test methods.

6. Terminology

6.1 For definitions of terms pertaining to tension testing, including tensile strength, yield point, yield strength, elongation, and reduction of area, reference should be made to Terminology E 6.

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

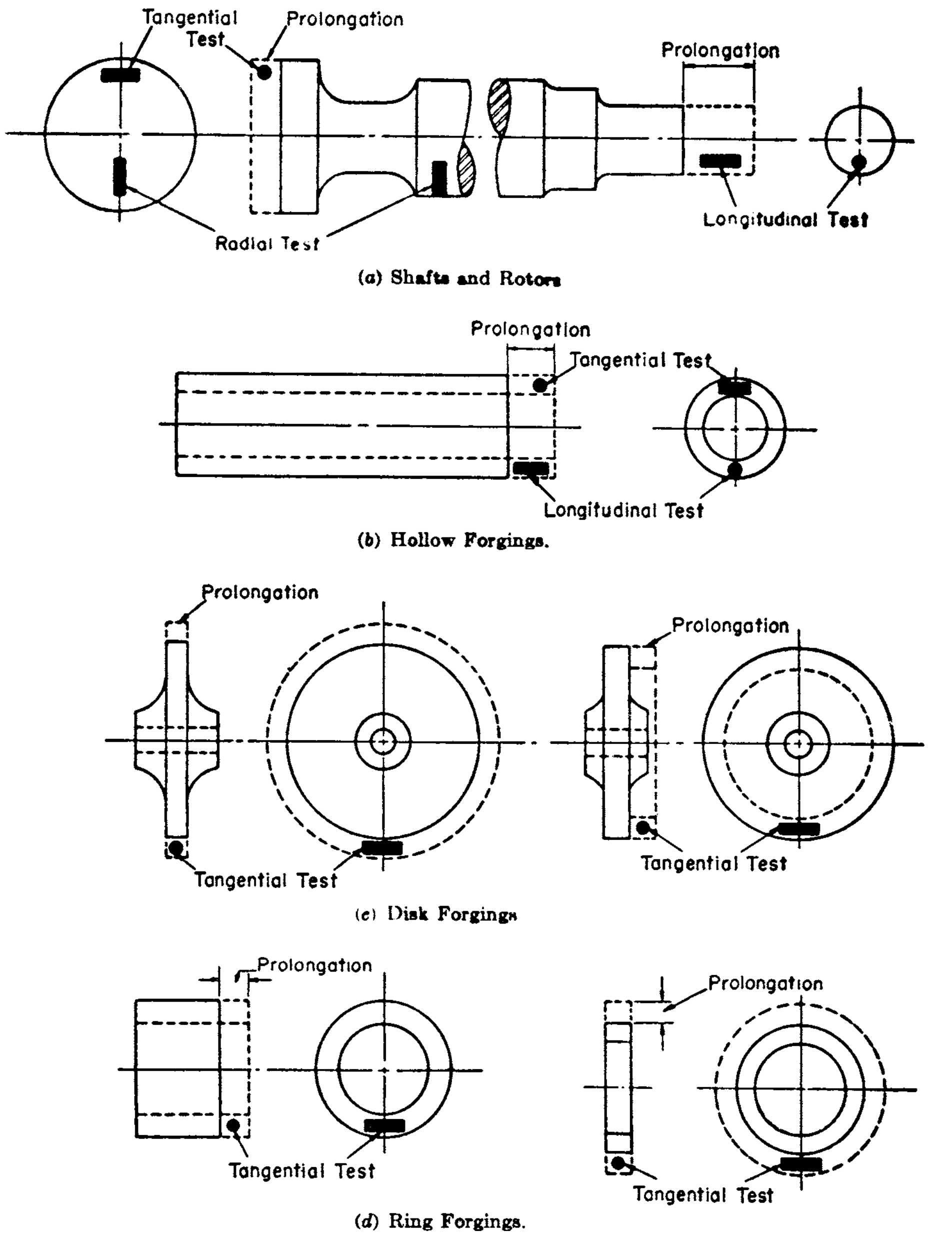


FIG. 2 Location of Longitudinal Tension Test Specimens in Rings Cut from Tubular Products

7. Testing Apparatus and Operations

7.1 *Loading Systems*—There are two general types of loading systems, mechanical (screw power) and hydraulic. These differ chiefly in the variability of the rate of load application. The older screw power machines are limited to a small number of fixed free running crosshead speeds. Some modern screw power machines, and all hydraulic machines permit stepless variation throughout the range of speeds.

7.2 The tension testing machine shall be maintained in good operating condition, used only in the proper loading range, and calibrated periodically in accordance with the latest revision of Practices E 4.

NOTE 1—Many machines are equipped with stress-strain recorders for autographic plotting of stress-strain curves. It should be noted that some recorders have a load measuring component entirely separate from the load indicator of the testing machine. Such recorders are calibrated separately.

7.3 *Loading*—It is the function of the gripping or holding device of the testing machine to transmit the load from the heads of the machine to the specimen under test. The essential requirement is that the load shall be transmitted axially. This implies that the centers of the action of the grips shall be in alignment, insofar as practicable, with the axis of the specimen at the beginning and during the test and that bending or twisting be held to a minimum. For specimens with a reduced section, gripping of the specimen shall be restricted to the grip section. In the case of certain sections tested in full size, nonaxial loading is unavoidable and in such cases shall be permissible.

7.4 *Speed of Testing*—The speed of testing shall not be greater than that at which load and strain readings can be made accurately. In production testing, speed of testing is commonly expressed: (*1*) in terms of free running crosshead speed (rate of movement of the crosshead of the testing machine when not under load), (*2*) in terms of rate of separation of the two heads of the testing machine under load, (*3*) in terms of rate of stressing the specimen, or (*4*) in terms of rate of straining the specimen. The following limitations on the speed of testing are recommended as adequate for most steel products:

NOTE 2—Tension tests using closed-loop machines (with feedback control of rate) should not be performed using load control, as this mode of testing will result in acceleration of the crosshead upon yielding and elevation of the measured yield strength.

7.4.1 Any convenient speed of testing may be used up to one half the specified yield point or yield strength. When this point is reached, the free-running rate of separation of the crossheads shall be adjusted so as not to exceed 1⁄16 in. per min per inch of reduced section, or the distance between the grips for test specimens not having reduced sections. This speed shall be maintained through the yield point or yield strength. In determining the tensile strength, the free-running rate of separation of the heads shall not exceed ½ in. per min per inch of reduced section, or the distance between the grips for test specimens not having reduced sections. In any event, the minimum speed of testing shall not be less than 1⁄10 the specified maximum rates for determining yield point or yield strength and tensile strength.

7.4.2 It shall be permissible to set the speed of the testing machine by adjusting the free running crosshead speed to the above specified values, inasmuch as the rate of separation of heads under load at these machine settings is less than the specified values of free running crosshead speed.

7.4.3 As an alternative, if the machine is equipped with a device to indicate the rate of loading, the speed of the machine from half the specified yield point or yield strength through the yield point or yield strength may be adjusted so that the rate of stressing does not exceed 100 000 psi (690 MPa)/min. However, the minimum rate of stressing shall not be less than 10 000 psi (70 MPa)/min.

8. Test Specimen Parameters

8.1 *Selection*—Test coupons shall be selected in accordance with the applicable product specifications.

8.1.1 *Wrought Steels*—Wrought steel products are usually tested in the longitudinal direction, but in some cases, where size permits and the service justifies it, testing is in the transverse, radial, or tangential directions (see Fig. 1 and Fig. 2).

8.1.2 *Forged Steels*—For open die forgings, the metal for tension testing is usually provided by allowing extensions or prolongations on one or both ends of the forgings, either on all or a representative number as provided by the applicable product specifications. Test specimens are normally taken at mid-radius. Certain product specifications permit the use of a representative bar or the destruction of a production part for test purposes. For ring or disk-like forgings test metal is provided by increasing the diameter, thickness, or length of the forging. Upset disk or ring forgings, which are worked or extended by forging in a direction perpendicular to the axis of the forging, usually have their principal extension along concentric circles and for such forgings tangential tension specimens are obtained from extra metal on the periphery or end of the forging. For some forgings, such as rotors, radial tension tests are required. In such cases the specimens are cut or trepanned from specified locations.

8.1.3 *Cast Steels*—Test coupons for castings from which tension test specimens are prepared shall be in accordance with the requirements of Specifications A 703/A 703M or A 781/A 781M, as applicable.

8.2 *Size and Tolerances*—Test specimens shall be the full thickness or section of material as-rolled, or may be machined to the form and dimensions shown in Figs. 3-6, inclusive. The selection of size and type of specimen is prescribed by the applicable product specification. Full section specimens shall be tested in 8-in. (200-mm) gauge length unless otherwise specified in the product specification.

8.3 *Procurement of Test Specimens*—Specimens shall be sheared, blanked, sawed, trepanned, or oxygen-cut from portions of the material. They are usually machined so as to have a reduced cross section at mid-length in order to obtain uniform distribution of the stress over the cross section and to localize the zone of fracture. When test coupons are sheared, blanked, sawed, or oxygen-cut, care shall be taken to remove by machining all distorted, cold-worked, or heat-affected areas from the edges of the section used in evaluating the test.

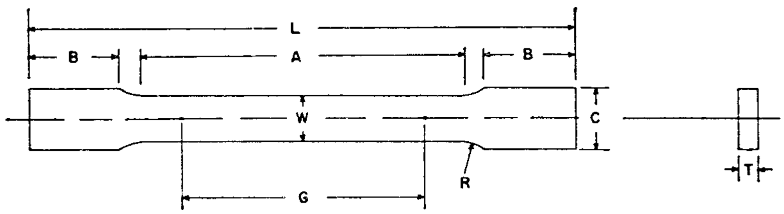
8.4 *Aging of Test Specimens*—Unless otherwise specified, it shall be permissible to age tension test specimens. The time-temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature 24 to 48 h, or in shorter time at moderately elevated temperatures by boiling in water, heating in oil or in an oven.

8.5 *Measurement of Dimensions of Test Specimens*:

8.5.1 *Standard Rectangular Tension Test Specimens*—These forms of specimens are shown in Fig. 3. To determine the cross-sectional area, the center width dimension shall be measured to the nearest 0.005 in. (0.13 mm) for the 8-in. (200-mm) gauge length specimen and 0.001 in. (0.025 mm) for the 2-in. (50-mm) gauge length specimen in Fig. 3. The center thickness dimension shall be measured to the nearest 0.001 in. for both specimens.

8.5.2 *Standard Round Tension Test Specimens*—These forms of specimens are shown in Fig. 4 and Fig. 5. To determine the cross-sectional area, the diameter shall be measured at the center of the gauge length to the nearest 0.001 in. (0.025 mm) (see Table 1).

8.6 *General*—Test specimens shall be either substantially full size or machined, as prescribed in the product specifications for the material being tested.



DIMENSIONS

	Standard Specimens						Subsize Specimen	
	Plate-Type, 1½-in. (40-mm) Wide				Sheet-Type, ½ in. (12.5-mm) Wide		¼-in. (6-mm) Wide	
	8-in. (200-mm) Gauge Length		2-in. (50-mm) Gauge Length					
	in.	mm	in.	mm	in.	mm	in.	mm
G—Gauge length (Notes 1 and 2)	8.00 ± 0.01	200 ± 0.25	2.000 ± 0.005	50.0 ± 0.10	2.000 ± 0.005	50.0 ± 0.010	1.000 ± 0.003	25.0 ± 0.08
W—Width (Notes 3, 5, and 6)	1½ + ⅛ − ¼	40 + 3 − 6	1½ + ⅛ − ¼	40 + 3 − 6	0.500 ± 0.010	12.5 ± 0.25	0.250 ± 0.002	6.25 ± 0.05
T—Thickness (Note 7)					Thickness of Material			
R—Radius of fillet, min (Note 4)	½	13	½	13	½	13	¼	6
L—Overall length, min (Notes 2 and 8)	18	450	8	200	8	200	4	100
A—Length of reduced section, min	9	225	2¼	60	2¼	60	1¼	32
B—Length of grip section, min (Note 9)	3	75	2	50	2	50	1¼	32
C—Width of grip section, approximate (Notes 4, 10, and 11)	2	50	2	50	¾	20	⅜	10

NOTE 1—For the 1½-in. (40-mm) wide specimens, punch marks for measuring elongation after fracture shall be made on the flat or on the edge of the specimen and within the reduced section. For the 8-in. (200-mm) gauge length specimen, a set of nine or more punch marks 1 in. (25 mm) apart, or one or more pairs of punch marks 8 in. (200 mm) apart may be used. For the 2-in. (50-mm) gauge length specimen, a set of three or more punch marks 1 in. (25 mm) apart, or one or more pairs of punch marks 2 in. (50 mm) apart may be used.

NOTE 2—For the ½-in. (12.5-mm) wide specimen, punch marks for measuring the elongation after fracture shall be made on the flat or on the edge of the specimen and within the reduced section. Either a set of three or more punch marks 1 in. (25 mm) apart or one or more pairs of punch marks 2 in. (50 mm) apart may be used.

NOTE 3—For the four sizes of specimens, the ends of the reduced section shall not differ in width by more than 0.004, 0.002, or 0.001 in. (0.10, 0.05, or 0.025 mm), respectively. Also, there may be a gradual decrease in width from the ends to the center, but the width at either end shall not be more than 0.015 in., 0.005 in., or 0.003 in. (0.40, 0.10 or 0.08 mm), respectively, larger than the width at the center.

NOTE 4—For each specimen type, the radii of all fillets shall be equal to each other with a tolerance of 0.05 in. (1.25 mm), and the centers of curvature of the two fillets at a particular end shall be located across from each other (on a line perpendicular to the centerline) within a tolerance of 0.10 in. (2.5 mm).

NOTE 5—For each of the four sizes of specimens, narrower widths (*W* and *C*) may be used when necessary. In such cases, the width of the reduced section should be as large as the width of the material being tested permits; however, unless stated specifically, the requirements for elongation in a product specification shall not apply when these narrower specimens are used. If the width of the material is less than *W*, the sides may be parallel throughout the length of the specimen.

NOTE 6—The specimen may be modified by making the sides parallel throughout the length of the specimen, the width and tolerances being the same as those specified above. When necessary, a narrower specimen may be used, in which case the width should be as great as the width of the material being tested permits. If the width is 1½ in. (38 mm) or less, the sides may be parallel throughout the length of the specimen.

NOTE 7—The dimension *T* is the thickness of the test specimen as provided for in the applicable product specification. Minimum nominal thickness of 1½-in. (40-mm) wide specimens shall be 3⁄16 in. (5 mm), except as permitted by the product specification. Maximum nominal thickness of ½-in. (12.5-mm) and ¼-in. (6-mm) wide specimens shall be ¾ in. (19 mm) and ¼ in. (6 mm), respectively.

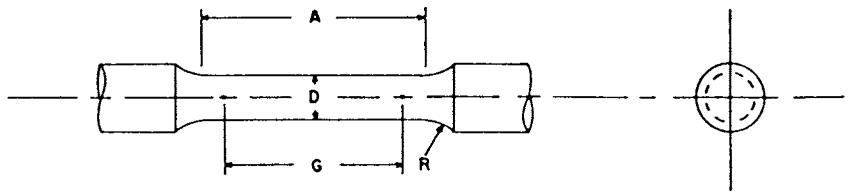
NOTE 8—To aid in obtaining axial loading during testing of ¼-in. (6-mm) wide specimens, the overall length should be as large as the material will permit.

NOTE 9—It is desirable, if possible, to make the length of the grip section large enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips. If the thickness of ½-in. (13-mm) wide specimens is over ⅜ in. (10 mm), longer grips and correspondingly longer grip sections of the specimen may be necessary to prevent failure in the grip section.

NOTE 10—For standard sheet-type specimens and subsize specimens, the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.01 and 0.005 in. (0.25 and 0.13 mm), respectively, except that for steel if the ends of the ½-in. (12.5-mm) wide specimen are symmetrical within 0.05 in. (1.0 mm), a specimen may be considered satisfactory for all but referee testing.

NOTE 11—For standard plate-type specimens, the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.25 in. (6.35 mm), except for referee testing in which case the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in. (2.5 mm).

FIG. 3 Rectangular Tension Test Specimens



DIMENSIONS

Nominal Diameter	Standard Specimen		Small-Size Specimens Proportional to Standard							
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
	0.500	12.5	0.350	8.75	0.250	6.25	0.160	4.00	0.113	2.50
G—Gauge length	2.00± 0.005	50.0 ± 0.10	1.400± 0.005	35.0 ± 0.10	1.000± 0.005	25.0 ± 0.10	0.640± 0.005	16.0 ± 0.10	0.450± 0.005	10.0 ± 0.10
D—Diameter (Note 1)	0.500± 0.010	12.5± 0.25	0.350± 0.007	8.75 ± 0.18	0.250± 0.005	6.25 ± 0.12	0.160± 0.003	4.00 ± 0.08	0.113± 0.002	2.50 ± 0.05
R—Radius of fillet, min	3⁄8	10	1⁄4	6	3⁄16	5	5⁄32	4	3⁄32	2
A—Length of reduced section, min (Note 2)	2 1⁄4	60	1 3⁄4	45	1 1⁄4	32	3⁄4	20	5⁄8	16

NOTE 1—The reduced section may have a gradual taper from the ends toward the center, with the ends not more than 1 percent larger in diameter than the center (controlling dimension).

NOTE 2—If desired, the length of the reduced section may be increased to accommodate an extensometer of any convenient gauge length. Reference marks for the measurement of elongation should, nevertheless, be spaced at the indicated gauge length.

NOTE 3—The gauge length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial (see Fig. 9). If the ends are to be held in wedge grips it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

NOTE 4—On the round specimens in Fig. 5 and Fig. 6, the gauge lengths are equal to four times the nominal diameter. In some product specifications other specimens may be provided for, but unless the 4-to-1 ratio is maintained within dimensional tolerances, the elongation values may not be comparable with those obtained from the standard test specimen.

NOTE 5—The use of specimens smaller than 0.250-in. (6.25-mm) diameter shall be restricted to cases when the material to be tested is of insufficient size to obtain larger specimens or when all parties agree to their use for acceptance testing. Smaller specimens require suitable equipment and greater skill in both machining and testing.

NOTE 6—Five sizes of specimens often used have diameters of approximately 0.505, 0.357, 0.252, 0.160, and 0.113 in., the reason being to permit easy calculations of stress from loads, since the corresponding cross sectional areas are equal or close to 0.200, 0.100, 0.0500, 0.0200, and 0.0100 in.^{2}, respectively. Thus, when the actual diameters agree with these values, the stresses (or strengths) may be computed using the simple multiplying factors 5, 10, 20, 50, and 100, respectively. (The metric equivalents of these fixed diameters do not result in correspondingly convenient cross sectional area and multiplying factors.)

FIG. 4 Standard 0.500-in. (12.5-mm) Round Tension Test Specimen with 2-in. (50-mm) Gauge Length and Examples of Small-Size Specimens Proportional to the Standard Specimens

8.6.1 Improperly prepared test specimens often cause unsatisfactory test results. It is important, therefore, that care be exercised in the preparation of specimens, particularly in the machining, to assure good workmanship.

8.6.2 It is desirable to have the cross-sectional area of the specimen smallest at the center of the gauge length to ensure fracture within the gauge length. This is provided for by the taper in the gauge length permitted for each of the specimens described in the following sections.

8.6.3 For brittle materials it is desirable to have fillets of large radius at the ends of the gauge length.

9. Plate-Type Specimens

9.1 The standard plate-type test specimens are shown in Fig. 3. Such specimens are used for testing metallic materials in the form of plate, structural and bar-size shapes, and flat material having a nominal thickness of 3⁄16 in. (5 mm) or over. When product specifications so permit, other types of specimens may be used.

NOTE 3—When called for in the product specification, the 8-in. (200-mm) gauge length specimen of Fig. 3 may be used for sheet and strip material.

10. Sheet-Type Specimen

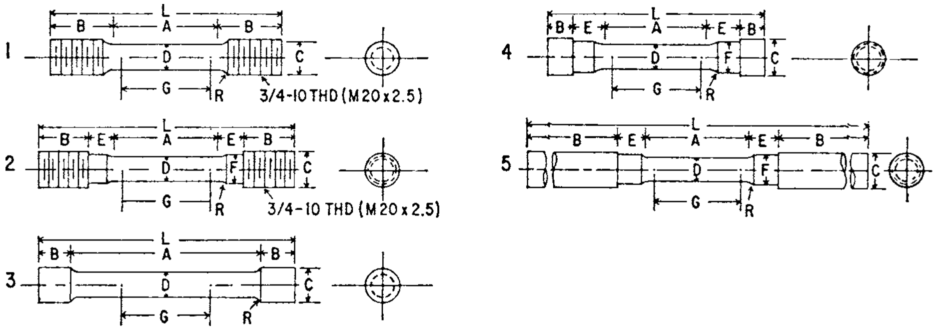
10.1 The standard sheet-type test specimen is shown in Fig. 3. This specimen is used for testing metallic materials in the form of sheet, plate, flat wire, strip, band, and hoop ranging in nominal thickness from 0.005 to 3⁄4 in. (0.13 to 19 mm). When product specifications so permit, other types of specimens may be used, as provided in Section 9 (see Note 3).

11. Round Specimens

11.1 The standard 0.500-in. (12.5-mm) diameter round test specimen shown in Fig. 4 is used quite generally for testing metallic materials, both cast and wrought.

11.2 Fig. 4 also shows small size specimens proportional to the standard specimen. These may be used when it is necessary to test material from which the standard specimen or specimens shown in Fig. 3 cannot be prepared. Other sizes of small round specimens may be used. In any such small size specimen it is important that the gauge length for measurement of elongation be four times the diameter of the specimen (see Note 4, Fig. 4).

11.3 The shape of the ends of the specimens outside of the gauge length shall be suitable to the material and of a shape to fit the holders or grips of the testing machine so that the loads



DIMENSIONS

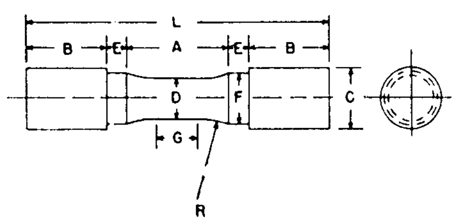
	Specimen 1		Specimen 2		Specimen 3		Specimen 4		Specimen 5	
	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
G—Gauge length	2.000± 0.005	50.0 ± 0.10	2.000± 0.005	50.0 ± 0.10	2.000± 0.005	50.0 ± 0.10	2.000± 0.005	50.0 ± 0.10	2.00± 0.005	50.0 ± 0.10
D—Diameter (Note 1)	0.500 ± 0.010	12.5± 0.25	0.500 ± 0.010	12.5± 0.25	0.500 ± 0.010	12.5± 0.25	0.500 ± 0.010	12.5± 0.25	0.500± 0.010	12.5 ± 0.25
R—Radius of fillet, min	3⁄8	10	3⁄8	10	1⁄16	2	3⁄8	10	3⁄8	10
A—Length of reduced section	2 1⁄4 , min	60, min	2 1⁄4 , min	60, min	4, approximately	100, approximately	2 1⁄4 , min	60, min	2 1⁄4 , min	60, min
L—Overall length, approximate	5	125	5 1⁄2	140	5 1⁄2	140	4 3⁄4	120	9 1⁄2	240
B—Grip section (Note 2)	1 3⁄8 , approximately	35, approximately	1, approximately	25, approximately	3⁄4 , approximately	20, approximately	1⁄2 , approximately	13, approximately	3, min	75, min
C—Diameter of end section	3⁄4	20	3⁄4	20	23⁄32	18	7⁄8	22	3⁄4	20
E—Length of shoulder and fillet section, approximate	. . .	. . .	5⁄8	16	. . .	. . .	3⁄4	20	5⁄8	16
F—Diameter of shoulder	. . .	. . .	5⁄8	16	. . .	. . .	5⁄8	16	19⁄32	15

NOTE 1—The reduced section may have a gradual taper from the ends toward the center with the ends not more than 0.005 in. (0.10 mm) larger in diameter than the center.

NOTE 2—On Specimen 5 it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

NOTE 3—The types of ends shown are applicable for the standard 0.500-in. round tension test specimen; similar types can be used for subsize specimens. The use of UNF series of threads (3⁄4 by 16, 1⁄2 by 20, 3⁄8 by 24, and 1⁄4 by 28) is suggested for high-strength brittle materials to avoid fracture in the thread portion.

FIG. 5 Suggested Types of Ends for Standard Round Tension Test Specimens



DIMENSIONS

	Specimen 1		Specimen 2		Specimen 3	
	in.	mm	in.	mm	in.	mm
G—Length of parallel	Shall be equal to or greater than diameter *D*					
D—Diameter	0.500 ± 0.010	12.5± 0.25	0.750 ± 0.015	20.0 ± 0.40	1.25 ± 0.025	30.0 ± 0.60
R—Radius of fillet, min	1	25	1	25	2	50
A—Length of reduced section, min	1 1⁄4	32	1 1⁄2	38	2 1⁄4	60
L—Over-all length, min	3 3⁄4	95	4	100	6 3⁄8	160
B—Grip section, approximate	1	25	1	25	1 3⁄4	45
C—Diameter of end section, approximate	3⁄4	20	1 1⁄8	30	1 7⁄8	48
E—Length of shoulder, min	1⁄4	6	1⁄4	6	5⁄16	8
F—Diameter of shoulder	5⁄8 ± 1⁄64	16.0 ± 0.40	15⁄16 ± 1⁄64	24.0 ± 0.40	1 7⁄16 ± 1⁄64	36.5 ± 0.40

NOTE 1—The reduced section and shoulders (dimensions *A, D, E, F, G,* and *R*) shall be shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. Commonly the ends are threaded and have the dimensions *B* and *C* given above.

FIG. 6 Standard Tension Test Specimens for Cast Iron

TABLE 1 Multiplying Factors to Be Used for Various Diameters of Round Test Specimens

Standard Specimen			Small Size Specimens Proportional to Standard					
0.500 in. Round			0.350 in. Round			0.250 in. Round		
Actual Diameter, in.	Area, in.^{2}	Multiplying Factor	Actual Diameter, in.	Area, in.^{2}	Multiplying Factor	Actual Diameter, in.	Area, in.^{2}	Multiplying Factor
0.490	0.1886	5.30	0.343	0.0924	10.82	0.245	0.0471	21.21
0.491	0.1893	5.28	0.344	0.0929	10.76	0.246	0.0475	21.04
0.492	0.1901	5.26	0.345	0.0935	10.70	0.247	0.0479	20.87
0.493	0.1909	5.24	0.346	0.0940	10.64	0.248	0.0483	20.70
0.494	0.1917	5.22	0.347	0.0946	10.57	0.249	0.0487	20.54
0.495	0.1924	5.20	0.348	0.0951	10.51	0.250	0.0491	20.37
0.496	0.1932	5.18	0.349	0.0957	10.45	0.251	0.0495 (0.05)^A	20.21 (20.0)^A
0.497	0.1940	5.15	0.350	0.0962	10.39	0.252	0.0499 (0.05)^A	20.05 (20.0)^A
0.498	0.1948	5.13	0.351	0.0968	10.33	0.253	0.0503 (0.05)^A	19.89 (20.0)^A
0.499	0.1956	5.11	0.352	0.0973	10.28	0.254	0.0507	19.74
0.500	0.1963	5.09	0.353	0.0979	10.22	0.255	0.0511	19.58
0.501	0.1971	5.07	0.354	0.0984	10.16	...	...	...
0.502	0.1979	5.05	0.355	0.0990	10.10	...	...	...
0.503	0.1987	5.03	0.356	0.0995 (0.1)^A	10.05 (10.0)^A	... ...	... ...	... ...
0.504	0.1995 (0.2)^A	5.01 (5.0)^A	0.357	0.1001 (0.1)^A	9.99 (10.0)^A	... ...	... ...	... ...
0.505	0.2003 (0.2)^A	4.99 (5.0)^A	...	...	...	...	...	...
0.506	0.2011 (0.2)^A	4.97 (5.0)^A	...	...	...	...	...	...
0.507	0.2019	4.95	...	...	...	...	...	...
0.508	0.2027	4.93	...	...	...	...	...	...
0.509	0.2035	4.91	...	...	...	...	...	...
0.510	0.2043	4.90	...	...	...	...	...	...

^{A} The values in parentheses may be used for ease in calculation of stresses, in pounds per square inch, as permitted in 5 of Fig. 4.

are applied axially. Fig. 5 shows specimens with various types of ends that have given satisfactory results.

12. Gauge Marks

12.1 The specimens shown in Figs. 3-6 shall be gauge marked with a center punch, scribe marks, multiple device, or drawn with ink. The purpose of these gauge marks is to determine the percent elongation. Punch marks shall be light, sharp, and accurately spaced. The localization of stress at the marks makes a hard specimen susceptible to starting fracture at the punch marks. The gauge marks for measuring elongation after fracture shall be made on the flat or on the edge of the flat tension test specimen and within the parallel section; for the 8-in. gauge length specimen, Fig. 3, one or more sets of 8-in. gauge marks may be used, intermediate marks within the gauge length being optional. Rectangular 2-in. gauge length specimens, Fig. 3, and round specimens, Fig. 4, are gauge marked with a double-pointed center punch or scribe marks. One or more sets of gauge marks may be used; however, one set must be approximately centered in the reduced section. These same precautions shall be observed when the test specimen is full section.

13. Determination of Tensile Properties

13.1 *Yield Point*—Yield point is the first stress in a material, less than the maximum obtainable stress, at which an increase in strain occurs without an increase in stress. Yield point is intended for application only for materials that may exhibit the unique characteristic of showing an increase in strain without an increase in stress. The stress-strain diagram is characterized by a sharp knee or discontinuity. Determine yield point by one of the following methods:

13.1.1 *Drop of the Beam or Halt of the Pointer Method*—In this method, apply an increasing load to the specimen at a uniform rate. When a lever and poise machine is used, keep the beam in balance by running out the poise at approximately a steady rate. When the yield point of the material is reached, the increase of the load will stop, but run the poise a trifle beyond the balance position, and the beam of the machine will drop for a brief but appreciable interval of time. When a machine equipped with a load-indicating dial is used there is a halt or hesitation of the load-indicating pointer corresponding to the drop of the beam. Note the load at the "drop of the beam" or the "halt of the pointer" and record the corresponding stress as the yield point.

13.1.2 *Autographic Diagram Method*—When a sharp-kneed stress-strain diagram is obtained by an autographic recording device, take the stress corresponding to the top of the knee (Fig. 7), or the stress at which the curve drops as the yield point.

13.1.3 *Total Extension Under Load Method*—When testing material for yield point and the test specimens may not exhibit a well-defined disproportionate deformation that characterizes a yield point as measured by the drop of the beam, halt of the pointer, or autographic diagram methods described in 13.1.1 and 13.1.2, a value equivalent to the yield point in its practical significance may be determined by the following method and may be recorded as yield point: Attach a Class C or better

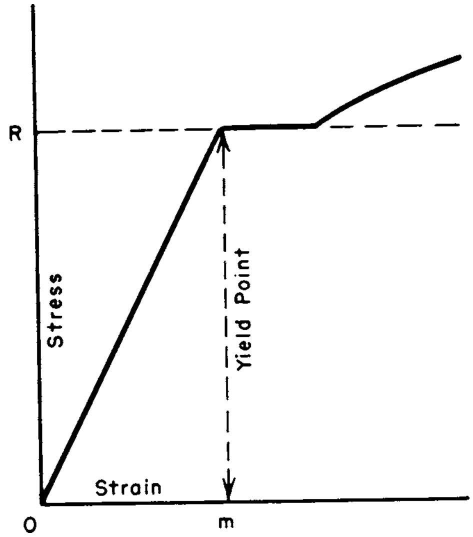


FIG. 7 Stress-Strain Diagram Showing Yield Point Corresponding with Top of Knee

extensometer (Note 4 and Note 5) to the specimen. When the load producing a specified extension (Note 6) is reached record the stress corresponding to the load as the yield point (Fig. 8).

NOTE 4—Automatic devices are available that determine the load at the specified total extension without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated. Multiplying calipers and other such devices are acceptable for use provided their accuracy has been demonstrated as equivalent to a Class C extensometer.

NOTE 5—Reference should be made to Practice E 83.

NOTE 6—For steel with a yield point specified not over 80 000 psi (550 MPa), an appropriate value is 0.005 in./in. of gauge length. For values above 80 000 psi, this method is not valid unless the limiting total extension is increased.

NOTE 7—The shape of the initial portion of an autographically determined stress-strain (or a load-elongation) curve may be influenced by numerous factors such as the seating of the specimen in the grips, the straightening of a specimen bent due to residual stresses, and the rapid loading permitted in 7.4.1. Generally, the aberrations in this portion of the curve should be ignored when fitting a modulus line, such as that used to determine the extension-under-load yield, to the curve.

13.2 *Yield Strength*—Yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. The deviation is expressed in terms of strain, percent offset, total extension under load, etc. Determine yield strength by one of the following methods:

13.2.1 *Offset Method*—To determine the yield strength by the "offset method," it is necessary to secure data (autographic or numerical) from which a stress-strain diagram with a distinct modulus characteristic of the material being tested may be drawn. Then on the stress-strain diagram (Fig. 9) lay off *Om* equal to the specified value of the offset, draw *mn* parallel to *OA*, and thus locate *r*, the intersection of *mn* with the stress-strain curve corresponding to load *R*, which is the yield-strength load. In recording values of yield strength obtained by this method, the value of offset specified or used, or both, shall be stated in parentheses after the term yield strength, for example:

$$\text{Yield strength } (0.2\ \%\text{ offset}) = 52\,000\ \text{psi } (360\ \text{MPa}) \quad (1)$$

When the offset is 0.2 % or larger, the extensometer used shall qualify as a Class B2 device over a strain range of 0.05 to 1.0 %. If a smaller offset is specified, it may be necessary to specify a more accurate device (that is, a Class B1 device) or reduce the lower limit of the strain range (for example, to 0.01 %) or both. See also Note 9 for automatic devices.

NOTE 8—For stress-strain diagrams not containing a distinct modulus, such as for some cold-worked materials, it is recommended that the extension under load method be utilized. If the offset method is used for materials without a distinct modulus, a modulus value appropriate for the material being tested should be used: 30 000 000 psi (207 000 MPa) for carbon steel; 29 000 000 psi (200 000 MPa) for ferritic stainless steel;

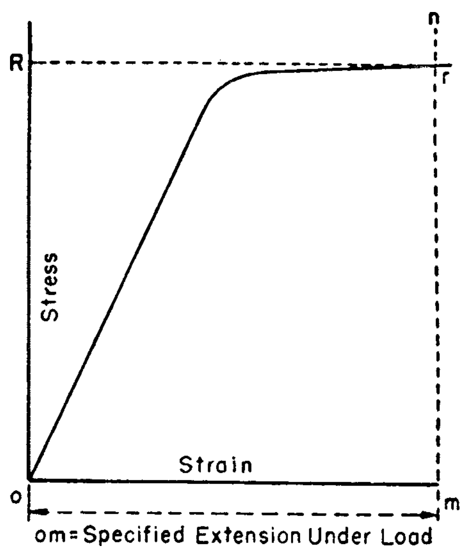


FIG. 8 Stress-Strain Diagram Showing Yield Point or Yield Strength by Extension Under Load Method

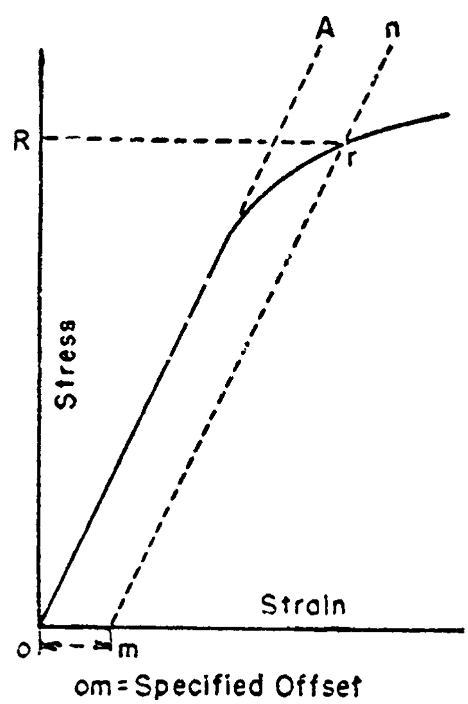


FIG. 9 Stress-Strain Diagram for Determination of Yield Strength by the Offset Method

28 000 000 psi (193 000 MPa) for austenitic stainless steel. For special alloys, the producer should be contacted to discuss appropriate modulus values.

13.2.2 *Extension Under Load Method*—For tests to determine the acceptance or rejection of material whose stress-strain characteristics are well known from previous tests of similar material in which stress-strain diagrams were plotted, the total strain corresponding to the stress at which the specified offset (see Note 9 and Note 10) occurs will be known within satisfactory limits. The stress on the specimen, when this total strain is reached, is the value of the yield strength. In recording values of yield strength obtained by this method, the value of "extension" specified or used, or both, shall be stated in parentheses after the term yield strength, for example:

$$\text{Yield strength } (0.5\ \%\ EUL) = 52\,000 \text{ psi } (360 \text{ MPa}) \quad (2)$$

The total strain can be obtained satisfactorily by use of a Class B1 extensometer (Note 4, Note 5, and Note 7).

NOTE 9—Automatic devices are available that determine offset yield strength without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated.

NOTE 10—The appropriate magnitude of the extension under load will obviously vary with the strength range of the particular steel under test. In general, the value of extension under load applicable to steel at any strength level may be determined from the sum of the proportional strain and the plastic strain expected at the specified yield strength. The following equation is used:

$$\text{Extension under load, in./in. of gauge length} = (YS/E) + r \quad (3)$$

where:
YS = specified yield strength, psi or MPa,
E = modulus of elasticity, psi or MPa, and
r = limiting plastic strain, in./in.

13.3 *Tensile Strength*— Calculate the tensile strength by dividing the maximum load the specimen sustains during a tension test by the original cross-sectional area of the specimen.

13.4 *Elongation*:

13.4.1 Fit the ends of the fractured specimen together carefully and measure the distance between the gauge marks to the nearest 0.01 in. (0.25 mm) for gauge lengths of 2 in. and under, and to the nearest 0.5 % of the gauge length for gauge lengths over 2 in. A percentage scale reading to 0.5 % of the gauge length may be used. The elongation is the increase in length of the gauge length, expressed as a percentage of the original gauge length. In recording elongation values, give both the percentage increase and the original gauge length.

13.4.2 If any part of the fracture takes place outside of the middle half of the gauge length or in a punched or scribed mark within the reduced section, the elongation value obtained may not be representative of the material. If the elongation so measured meets the minimum requirements specified, no further testing is indicated, but if the elongation is less than the minimum requirements, discard the test and retest.

13.4.3 Automated tensile testing methods using extensometers allow for the measurement of elongation in a method described below. Elongation may be measured and reported either this way, or as in the method described above, fitting the broken ends together. Either result is valid.

13.4.4 Elongation at fracture is defined as the elongation measured just prior to the sudden decrease in force associated with fracture. For many ductile materials not exhibiting a sudden decrease in force, the elongation at fracture can be taken as the strain measured just prior to when the force falls below 10 % of the maximum force encountered during the test.

13.4.4.1 Elongation at fracture shall include elastic and plastic elongation and may be determined with autographic or automated methods using extensometers verified over the strain range of interest. Use a class B2 or better extensometer for materials having less than 5 % elongation; a class C or better extensometer for materials having elongation greater than or equal to 5 % but less than 50 %; and a class D or better extensometer for materials having 50 % or greater elongation. In all cases, the extensometer gauge length shall be the nominal gauge length required for the specimen being tested. Due to the lack of precision in fitting fractured ends together, the elongation after fracture using the manual methods of the preceding paragraphs may differ from the elongation at fracture determined with extensometers.

13.4.4.2 Percent elongation at fracture may be calculated directly from elongation at fracture data and be reported instead of percent elongation as calculated in 13.4.1. However, these two parameters are not interchangeable. Use of the elongation at fracture method generally provides more repeatable results.

13.5 *Reduction of Area*—Fit the ends of the fractured specimen together and measure the mean diameter or the width and thickness at the smallest cross section to the same accuracy as the original dimensions. The difference between the area thus found and the area of the original cross section expressed as a percentage of the original area is the reduction of area.

BEND TEST

14. Description

14.1 The bend test is one method for evaluating ductility, but it cannot be considered as a quantitative means of predicting service performance in bending operations. The severity of the bend test is primarily a function of the angle of bend of the inside diameter to which the specimen is bent, and of the cross section of the specimen. These conditions are varied according to location and orientation of the test specimen and the chemical composition, tensile properties, hardness, type, and quality of the steel specified. Test Method E 190 and Test Method E 290 may be consulted for methods of performing the test.

14.2 Unless otherwise specified, it shall be permissible to age bend test specimens. The time-temperature cycle employed must be such that the effects of previous processing will not be materially changed. It may be accomplished by aging at room temperature 24 to 48 h, or in shorter time at moderately elevated temperatures by boiling in water or by heating in oil or in an oven.

14.3 Bend the test specimen at room temperature to an inside diameter, as designated by the applicable product specifications, to the extent specified without major cracking on the outside of the bent portion. The speed of bending is ordinarily not an important factor.

HARDNESS TEST

15. General

15.1 A hardness test is a means of determining resistance to penetration and is occasionally employed to obtain a quick approximation of tensile strength. Table 2, Table 3, Table 4, and Table 5 are for the conversion of hardness measurements from one scale to another or to approximate tensile strength. These conversion values have been obtained from computer-generated curves and are presented to the nearest 0.1 point to permit accurate reproduction of those curves. Since all converted hardness values must be considered approximate, however, all converted Rockwell hardness numbers shall be rounded to the nearest whole number.

15.2 *Hardness Testing*:

15.2.1 If the product specification permits alternative hardness testing to determine conformance to a specified hardness requirement, the conversions listed in Table 2, Table 3, Table 4, and Table 5 shall be used.

15.2.2 When recording converted hardness numbers, the measured hardness and test scale shall be indicated in parentheses, for example: 353 HB (38 HRC). This means that a hardness value of 38 was obtained using the Rockwell C scale and converted to a Brinell hardness of 353.

16. Brinell Test

16.1 *Description*:

16.1.1 A specified load is applied to a flat surface of the specimen to be tested, through a hard ball of specified diameter. The average diameter of the indentation is used as a basis for calculation of the Brinell hardness number. The quotient of the applied load divided by the area of the surface of the indentation, which is assumed to be spherical, is termed the Brinell hardness number (HB) in accordance with the following equation:

$$HB = P/[(\pi D/2)(D - \sqrt{D^2 - d^2})] \qquad (4)$$

where:

HB = Brinell hardness number,
P = applied load, kgf,
D = diameter of the steel ball, mm, and
d = average diameter of the indentation, mm.

NOTE 11—The Brinell hardness number is more conveniently secured from standard tables such as Table 6, which show numbers corresponding to the various indentation diameters, usually in increments of 0.05 mm.

NOTE 12—In Test Method E 10 the values are stated in SI units, whereas in this section kg/m units are used.

16.1.2 The standard Brinell test using a 10-mm ball employs a 3000-kgf load for hard materials and a 1500 or 500-kgf load for thin sections or soft materials (see Annex A2 on Steel Tubular Products). Other loads and different size indentors may be used when specified. In recording hardness values, the diameter of the ball and the load must be stated except when a 10-mm ball and 3000-kgf load are used.

16.1.3 A range of hardness can properly be specified only for quenched and tempered or normalized and tempered material. For annealed material a maximum figure only should be specified. For normalized material a minimum or a maximum hardness may be specified by agreement. In general, no hardness requirements should be applied to untreated material.

16.1.4 Brinell hardness may be required when tensile properties are not specified.

16.2 *Apparatus*—Equipment shall meet the following requirements:

16.2.1 *Testing Machine*— A Brinell hardness testing machine is acceptable for use over a loading range within which its load measuring device is accurate to ±1 %.

16.2.2 *Measuring Microscope*—The divisions of the micrometer scale of the microscope or other measuring devices used for the measurement of the diameter of the indentations shall be such as to permit the direct measurement of the diameter to 0.1 mm and the estimation of the diameter to 0.05 mm.

NOTE 13—This requirement applies to the construction of the microscope only and is not a requirement for measurement of the indentation, see 16.4.3.

16.2.3 *Standard Ball*— The standard ball for Brinell hardness testing is 10 mm (0.3937 in.) in diameter with a deviation from this value of not more than 0.005 mm (0.0004 in.) in any diameter. A ball suitable for use must not show a permanent change in diameter greater than 0.01 mm (0.0004 in.) when pressed with a force of 3000 kgf against the test specimen.

16.3 *Test Specimen*—Brinell hardness tests are made on prepared areas and sufficient metal must be removed from the surface to eliminate decarburized metal and other surface irregularities. The thickness of the piece tested must be such that no bulge or other marking showing the effect of the load appears on the side of the piece opposite the indentation.

16.4 *Procedure*:

16.4.1 It is essential that the applicable product specifications state clearly the position at which Brinell hardness indentations are to be made and the number of such indentations required. The distance of the center of the indentation from the edge of the specimen or edge of another indentation must be at least two and one-half times the diameter of the indentation.

16.4.2 Apply the load for 10 to 15 s.

16.4.3 Measure two diameters of the indentation at right angles to the nearest 0.1 mm, estimate to the nearest 0.05 mm, and average to the nearest 0.05 mm. If the two diameters differ by more than 0.1 mm, discard the readings and make a new indentation.

16.4.4 Do not use a steel ball on steels having a hardness over 450 HB nor a carbide ball on steels having a hardness over 650 HB. The Brinell hardness test is not recommended for materials having a hardness over 650 HB.

16.4.4.1 If a ball is used in a test of a specimen which shows a Brinell hardness number greater than the limit for the ball as detailed in 16.4.4, the ball shall be either discarded and replaced with a new ball or remeasured to ensure conformance with the requirements of Test Method E 10.

16.5 *Detailed Procedure*—For detailed requirements of this test, reference shall be made to the latest revision of Test Method E 10.

TABLE 2 Approximate Hardness Conversion Numbers for Nonaustenitic Steels[A] (Rockwell C to Other Hardness Numbers)

Rockwell C Scale, 150-kgf Load, Diamond Penetrator	Vickers Hardness Number	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness			Approximate Tensile Strength, ksi (MPa)
					15N Scale, 15-kgf Load, Diamond Penetrator	30N Scale 30-kgf Load, Diamond Penetrator	45N Scale, 45-kgf Load, Diamond Penetrator	
68	940	. . .	920	85.6	93.2	84.4	75.4	. . .
67	900	. . .	895	85.0	92.9	83.6	74.2	. . .
66	865	. . .	870	84.5	92.5	82.8	73.3	. . .
65	832	739	846	83.9	92.2	81.9	72.0	. . .
64	800	722	822	83.4	91.8	81.1	71.0	. . .
63	772	706	799	82.8	91.4	80.1	69.9	. . .
62	746	688	776	82.3	91.1	79.3	68.8	. . .
61	720	670	754	81.8	90.7	78.4	67.7	. . .
60	697	654	732	81.2	90.2	77.5	66.6	. . .
59	674	634	710	80.7	89.8	76.6	65.5	351 (2420)
58	653	615	690	80.1	89.3	75.7	64.3	338 (2330)
57	633	595	670	79.6	88.9	74.8	63.2	325 (2240)
56	613	577	650	79.0	88.3	73.9	62.0	313 (2160)
55	595	560	630	78.5	87.9	73.0	60.9	301 (2070)
54	577	543	612	78.0	87.4	72.0	59.8	292 (2010)
53	560	525	594	77.4	86.9	71.2	58.6	283 (1950)
52	544	512	576	76.8	86.4	70.2	57.4	273 (1880)
51	528	496	558	76.3	85.9	69.4	56.1	264 (1820)
50	513	482	542	75.9	85.5	68.5	55.0	255 (1760)
49	498	468	526	75.2	85.0	67.6	53.8	246 (1700)
48	484	455	510	74.7	84.5	66.7	52.5	238 (1640)
47	471	442	495	74.1	83.9	65.8	51.4	229 (1580)
46	458	432	480	73.6	83.5	64.8	50.3	221 (1520)
45	446	421	466	73.1	83.0	64.0	49.0	215 (1480)
44	434	409	452	72.5	82.5	63.1	47.8	208 (1430)
43	423	400	438	72.0	82.0	62.2	46.7	201 (1390)
42	412	390	426	71.5	81.5	61.3	45.5	194 (1340)
41	402	381	414	70.9	80.9	60.4	44.3	188 (1300)
40	392	371	402	70.4	80.4	59.5	43.1	182 (1250)
39	382	362	391	69.9	79.9	58.6	41.9	177 (1220)
38	372	353	380	69.4	79.4	57.7	40.8	171 (1180)
37	363	344	370	68.9	78.8	56.8	39.6	166 (1140)
36	354	336	360	68.4	78.3	55.9	38.4	161 (1110)
35	345	327	351	67.9	77.7	55.0	37.2	156 (1080)
34	336	319	342	67.4	77.2	54.2	36.1	152 (1050)
33	327	311	334	66.8	76.6	53.3	34.9	149 (1030)
32	318	301	326	66.3	76.1	52.1	33.7	146 (1010)
31	310	294	318	65.8	75.6	51.3	32.5	141 (970)
30	302	286	311	65.3	75.0	50.4	31.3	138 (950)
29	294	279	304	64.6	74.5	49.5	30.1	135 (930)
28	286	271	297	64.3	73.9	48.6	28.9	131 (900)
27	279	264	290	63.8	73.3	47.7	27.8	128 (880)
26	272	258	284	63.3	72.8	46.8	26.7	125 (860)
25	266	253	278	62.8	72.2	45.9	25.5	123 (850)
24	260	247	272	62.4	71.6	45.0	24.3	119 (820)
23	254	243	266	62.0	71.0	44.0	23.1	117 (810)
22	248	237	261	61.5	70.5	43.2	22.0	115 (790)
21	243	231	256	61.0	69.9	42.3	20.7	112 (770)
20	238	226	251	60.5	69.4	41.5	19.6	110 (760)

[A] This table gives the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. The data in this table should not be used to establish a relationship between hardness values and tensile strength of hard drawn wire. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

TABLE 3 Approximate Hardness Conversion Numbers for Nonaustenitic Steels[A] (Rockwell B to Other Hardness Numbers)

Rockwell B Scale, 100-kgf Load 1⁄16-in. (1.588-mm) Ball	Vickers Hardness Number	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell F Scale, 60-kgf Load, 1⁄16-in. (1.588-mm) Ball	Rockwell Superficial Hardness 15T Scale, 15-kgf Load, 1⁄16-in. (1.588-mm) Ball	Rockwell Superficial Hardness 30T Scale, 30-kgf Load, 1⁄16-in. (1.588-mm) Ball	Rockwell Superficial Hardness 45T Scale, 45-kgf Load, 1⁄16-in. (1.588-mm) Ball	Approximate Tensile Strength ksi (MPa)
100	240	240	251	61.5	...	93.1	83.1	72.9	116 (800)
99	234	234	246	60.9	...	92.8	82.5	71.9	114 (785)
98	228	228	241	60.2	...	92.5	81.8	70.9	109 (750)
97	222	222	236	59.5	...	92.1	81.1	69.9	104 (715)
96	216	216	231	58.9	...	91.8	80.4	68.9	102 (705)
95	210	210	226	58.3	...	91.5	79.8	67.9	100 (690)
94	205	205	221	57.6	...	91.2	79.1	66.9	98 (675)
93	200	200	216	57.0	...	90.8	78.4	65.9	94 (650)
92	195	195	211	56.4	...	90.5	77.8	64.8	92 (635)
91	190	190	206	55.8	...	90.2	77.1	63.8	90 (620)
90	185	185	201	55.2	...	89.9	76.4	62.8	89 (615)
89	180	180	196	54.6	...	89.5	75.8	61.8	88 (605)
88	176	176	192	54.0	...	89.2	75.1	60.8	86 (590)
87	172	172	188	53.4	...	88.9	74.4	59.8	84 (580)
86	169	169	184	52.8	...	88.6	73.8	58.8	83 (570)
85	165	165	180	52.3	...	88.2	73.1	57.8	82 (565)
84	162	162	176	51.7	...	87.9	72.4	56.8	81 (560)
83	159	159	173	51.1	...	87.6	71.8	55.8	80 (550)
82	156	156	170	50.6	...	87.3	71.1	54.8	77 (530)
81	153	153	167	50.0	...	86.9	70.4	53.8	73 (505)
80	150	150	164	49.5	...	86.6	69.7	52.8	72 (495)
79	147	147	161	48.9	...	86.3	69.1	51.8	70 (485)
78	144	144	158	48.4	...	86.0	68.4	50.8	69 (475)
77	141	141	155	47.9	...	85.6	67.7	49.8	68 (470)
76	139	139	152	47.3	...	85.3	67.1	48.8	67 (460)
75	137	137	150	46.8	99.6	85.0	66.4	47.8	66 (455)
74	135	135	147	46.3	99.1	84.7	65.7	46.8	65 (450)
73	132	132	145	45.8	98.5	84.3	65.1	45.8	64 (440)
72	130	130	143	45.3	98.0	84.0	64.4	44.8	63 (435)
71	127	127	141	44.8	97.4	83.7	63.7	43.8	62 (425)
70	125	125	139	44.3	96.8	83.4	63.1	42.8	61 (420)
69	123	123	137	43.8	96.2	83.0	62.4	41.8	60 (415)
68	121	121	135	43.3	95.6	82.7	61.7	40.8	59 (405)
67	119	119	133	42.8	95.1	82.4	61.0	39.8	58 (400)
66	117	117	131	42.3	94.5	82.1	60.4	38.7	57 (395)
65	116	116	129	41.8	93.9	81.8	59.7	37.7	56 (385)
64	114	114	127	41.4	93.4	81.4	59.0	36.7	...
63	112	112	125	40.9	92.8	81.1	58.4	35.7	...
62	110	110	124	40.4	92.2	80.8	57.7	34.7	...
61	108	108	122	40.0	91.7	80.5	57.0	33.7	...
60	107	107	120	39.5	91.1	80.1	56.4	32.7	...
59	106	106	118	39.0	90.5	79.8	55.7	31.7	...
58	104	104	117	38.6	90.0	79.5	55.0	30.7	...
57	103	103	115	38.1	89.4	79.2	54.4	29.7	...
56	101	101	114	37.7	88.8	78.8	53.7	28.7	...
55	100	100	112	37.2	88.2	78.5	53.0	27.7	...
54	...	...	111	36.8	87.7	78.2	52.4	26.7	...
53	...	...	110	36.3	87.1	77.9	51.7	25.7	...
52	...	...	109	35.9	86.5	77.5	51.0	24.7	...
51	...	...	108	35.5	86.0	77.2	50.3	23.7	...
50	...	...	107	35.0	85.4	76.9	49.7	22.7	...
49	...	...	106	34.6	84.8	76.6	49.0	21.7	...
48	...	...	105	34.1	84.3	76.2	48.3	20.7	...
47	...	...	104	33.7	83.7	75.9	47.7	19.7	...
46	...	...	103	33.3	83.1	75.6	47.0	18.7	...
45	...	...	102	32.9	82.6	75.3	46.3	17.7	...
44	...	...	101	32.4	82.0	74.9	45.7	16.7	...
43	...	...	100	32.0	81.4	74.6	45.0	15.7	...
42	...	...	99	31.6	80.8	74.3	44.3	14.7	...
41	...	...	98	31.2	80.3	74.0	43.7	13.6	...
40	...	...	97	30.7	79.7	73.6	43.0	12.6	...
39	...	...	96	30.3	79.1	73.3	42.3	11.6	...
38	...	...	95	29.9	78.6	73.0	41.6	10.6	...
37	...	...	94	29.5	78.0	72.7	41.0	9.6	...
36	...	...	93	29.1	77.4	72.3	40.3	8.6	...
35	...	...	92	28.7	76.9	72.0	39.6	7.6	...
34	...	...	91	28.2	76.3	71.7	39.0	6.6	...
33	...	...	90	27.8	75.7	71.4	38.3	5.6	...

TABLE 3 *Continued*

Rockwell B Scale, 100-kgf Load 1⁄16-in. (1.588-mm) Ball	Vickers Hardness Number	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Knoop Hardness, 500-gf Load and Over	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell F Scale, 60-kgf Load, 1⁄16-in. (1.588-mm) Ball	Rockwell Superficial Hardness			Approximate Tensile Strength ksi (MPa)
						15T Scale, 15-kgf Load, 1⁄16 -in. (1.588-mm) Ball	30T Scale, 30-kgf Load, 1⁄16-in. (1.588-mm) Ball	45T Scale, 45-kgf Load, 1⁄16-in. (1.588-mm) Ball	
32	. . .	. . .	89	27.4	75.2	71.0	37.6	4.6	. . .
31	. . .	. . .	88	27.0	74.6	70.7	37.0	3.6	. . .
30	. . .	. . .	87	26.6	74.0	70.4	36.3	2.6	. . .

[A] This table gives the approximate interrelationships of hardness values and approximate tensile strength of steels. It is possible that steels of various compositions and processing histories will deviate in hardness-tensile strength relationship from the data presented in this table. The data in this table should not be used for austenitic stainless steels, but have been shown to be applicable for ferritic and martensitic stainless steels. The data in this table should not be used to establish a relationship between hardness values and tensile strength of hard drawn wire. Where more precise conversions are required, they should be developed specially for each steel composition, heat treatment, and part.

TABLE 4 Approximate Hardness Conversion Numbers for Austenitic Steels (Rockwell C to other Hardness Numbers)

Rockwell C Scale, 150-kgf Load, Diamond Penetrator	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness		
		15N Scale, 15-kgf Load, Diamond Penetrator	30N Scale, 30-kgf Load, Diamond Penetrator	45N Scale, 45-kgf Load, Diamond Penetrator
48	74.4	84.1	66.2	52.1
47	73.9	83.6	65.3	50.9
46	73.4	83.1	64.5	49.8
45	72.9	82.6	63.6	48.7
44	72.4	82.1	62.7	47.5
43	71.9	81.6	61.8	46.4
42	71.4	81.0	61.0	45.2
41	70.9	80.5	60.1	44.1
40	70.4	80.0	59.2	43.0
39	69.9	79.5	58.4	41.8
38	69.3	79.0	57.5	40.7
37	68.8	78.5	56.6	39.6
36	68.3	78.0	55.7	38.4
35	67.8	77.5	54.9	37.3
34	67.3	77.0	54.0	36.1
33	66.8	76.5	53.1	35.0
32	66.3	75.9	52.3	33.9
31	65.8	75.4	51.4	32.7
30	65.3	74.9	50.5	31.6
29	64.8	74.4	49.6	30.4
28	64.3	73.9	48.8	29.3
27	63.8	73.4	47.9	28.2
26	63.3	72.9	47.0	27.0
25	62.8	72.4	46.2	25.9
24	62.3	71.9	45.3	24.8
23	61.8	71.3	44.4	23.6
22	61.3	70.8	43.5	22.5
21	60.8	70.3	42.7	21.3
20	60.3	69.8	41.8	20.2

17. Rockwell Test

17.1 *Description*:

17.1.1 In this test a hardness value is obtained by determining the depth of penetration of a diamond point or a steel ball into the specimen under certain arbitrarily fixed conditions. A minor load of 10 kgf is first applied which causes an initial penetration, sets the penetrator on the material and holds it in position. A major load which depends on the scale being used is applied increasing the depth of indentation. The major load is removed and, with the minor load still acting, the Rockwell number, which is proportional to the difference in penetration between the major and minor loads is determined; this is usually done by the machine and shows on a dial, digital display, printer, or other device. This is an arbitrary number which increases with increasing hardness. The scales most frequently used are as follows:

Scale Symbol	Penetrator	Major Load, kgf	Minor Load, kgf
B	1⁄16-in. steel ball	100	10
C	Diamond brale	150	10

17.1.2 Rockwell superficial hardness machines are used for the testing of very thin steel or thin surface layers. Loads of 15, 30, or 45 kgf are applied on a hardened steel ball or diamond

TABLE 5 Approximate Hardness Conversion Numbers for Austenitic Steels (Rockwell B to other Hardness Numbers)

Rockwell B Scale, 100-kgf Load, 1⁄16-in. (1.588-mm) Ball	Brinell Indentation Diameter, mm	Brinell Hardness, 3000-kgf Load, 10-mm Ball	Rockwell A Scale, 60-kgf Load, Diamond Penetrator	Rockwell Superficial Hardness		
				15T Scale, 15-kgf Load, 1⁄16-in. (1.588-mm) Ball	30T Scale, 30-kgf Load, 1⁄16-in. (1.588-mm) Ball	45T Scale, 45-kgf Load, 1⁄16-in. (1.588-mm) Ball
100	3.79	256	61.5	91.5	80.4	70.2
99	3.85	248	60.9	91.2	79.7	69.2
98	3.91	240	60.3	90.8	79.0	68.2
97	3.96	233	59.7	90.4	78.3	67.2
96	4.02	226	59.1	90.1	77.7	66.1
95	4.08	219	58.5	89.7	77.0	65.1
94	4.14	213	58.0	89.3	76.3	64.1
93	4.20	207	57.4	88.9	75.6	63.1
92	4.24	202	56.8	88.6	74.9	62.1
91	4.30	197	56.2	88.2	74.2	61.1
90	4.35	192	55.6	87.8	73.5	60.1
89	4.40	187	55.0	87.5	72.8	59.0
88	4.45	183	54.5	87.1	72.1	58.0
87	4.51	178	53.9	86.7	71.4	57.0
86	4.55	174	53.3	86.4	70.7	56.0
85	4.60	170	52.7	86.0	70.0	55.0
84	4.65	167	52.1	85.6	69.3	54.0
83	4.70	163	51.5	85.2	68.6	52.9
82	4.74	160	50.9	84.9	67.9	51.9
81	4.79	156	50.4	84.5	67.2	50.9
80	4.84	153	49.8	84.1	66.5	49.9

penetrator, to cover the same range of hardness values as for the heavier loads. The superficial hardness scales are as follows:

Scale Symbol	Penetrator	Major Load, kgf	Minor Load, kgf
15T	1⁄16-in. steel ball	15	3
30T	1⁄16-in. steel ball	30	3
45T	1⁄16-in. steel ball	45	3
15N	Diamond brale	15	3
30N	Diamond brale	30	3
45N	Diamond brale	45	3

17.2 *Reporting Hardness*—In recording hardness values, the hardness number shall always precede the scale symbol, for example: 96 HRB, 40 HRC, 75 HR15N, or 77 HR30T.

17.3 *Test Blocks*—Machines should be checked to make certain they are in good order by means of standardized Rockwell test blocks.

17.4 *Detailed Procedure*—For detailed requirements of this test, reference shall be made to the latest revision of Test Methods E 18.

18. Portable Hardness Test

18.1 Although the use of the standard, stationary Brinell or Rockwell hardness tester is generally preferred, it is not always possible to perform the hardness test using such equipment due to the part size or location. In this event, hardness testing using portable equipment as described in Practice A 833 or Test Method E 110 shall be used.

CHARPY IMPACT TESTING

19. Summary

19.1 A Charpy V-notch impact test is a dynamic test in which a notched specimen is struck and broken by a single blow in a specially designed testing machine. The measured test values may be the energy absorbed, the percentage shear fracture, the lateral expansion opposite the notch, or a combination thereof.

19.2 Testing temperatures other than room (ambient) temperature often are specified in product or general requirement specifications (hereinafter referred to as the specification). Although the testing temperature is sometimes related to the expected service temperature, the two temperatures need not be identical.

20. Significance and Use

20.1 *Ductile vs. Brittle Behavior*—Body-centered-cubic or ferritic alloys exhibit a significant transition in behavior when impact tested over a range of temperatures. At temperatures above transition, impact specimens fracture by a ductile (usually microvoid coalescence) mechanism, absorbing relatively large amounts of energy. At lower temperatures, they fracture in a brittle (usually cleavage) manner absorbing less energy. Within the transition range, the fracture will generally be a mixture of areas of ductile fracture and brittle fracture.

20.2 The temperature range of the transition from one type of behavior to the other varies according to the material being tested. This transition behavior may be defined in various ways for specification purposes.

20.2.1 The specification may require a minimum test result for absorbed energy, fracture appearance, lateral expansion, or a combination thereof, at a specified test temperature.

20.2.2 The specification may require the determination of the transition temperature at which either the absorbed energy or fracture appearance attains a specified level when testing is performed over a range of temperatures.

20.3 Further information on the significance of impact testing appears in Annex A5.

TABLE 6 Brinell Hardness Numbers[A]
(Ball 10 mm in Diameter, Applied Loads of 500, 1500, and 3000 kgf)

Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number			Diameter of Indentation, mm	Brinell Hardness Number		
	500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load
2.00	*158*	*473*	*945*	2.60	92.6	278	555	3.20	60.5	182	363	3.80	42.4	127	255
2.01	*156*	*468*	*936*	2.61	91.8	276	551	3.21	60.1	180	361	3.81	42.2	127	253
2.02	*154*	*463*	*926*	2.62	91.1	273	547	3.22	59.8	179	359	3.82	42.0	126	252
2.03	*153*	*459*	*917*	2.63	90.4	271	543	3.23	59.4	178	356	3.83	41.7	125	250
2.04	*151*	*454*	*908*	2.64	89.7	269	538	3.24	59.0	177	354	3.84	41.5	125	249
2.05	*150*	*450*	*899*	2.65	89.0	267	534	3.25	58.6	176	352	3.85	41.3	124	248
2.06	*148*	*445*	*890*	2.66	88.4	265	530	3.26	58.3	175	350	3.86	41.1	123	246
2.07	*147*	*441*	*882*	2.67	87.7	263	526	3.27	57.9	174	347	3.87	40.9	123	245
2.08	*146*	*437*	*873*	2.68	87.0	261	522	3.28	57.5	173	345	3.88	40.6	122	244
2.09	*144*	*432*	*865*	2.69	86.4	259	518	3.29	57.2	172	343	3.89	40.4	121	242
2.10	*143*	*428*	*856*	2.70	85.7	257	514	3.30	56.8	170	341	3.90	40.2	121	241
2.11	*141*	*424*	*848*	2.71	85.1	255	510	3.31	56.5	169	339	3.91	40.0	120	240
2.12	*140*	*420*	*840*	2.72	84.4	253	507	3.32	56.1	168	337	3.92	39.8	119	239
2.13	*139*	*416*	*832*	2.73	83.8	251	503	3.33	55.8	167	335	3.93	39.6	119	237
2.14	*137*	*412*	*824*	2.74	83.2	250	499	3.34	55.4	166	333	3.94	39.4	118	236
2.15	*136*	*408*	*817*	2.75	82.6	248	495	3.35	55.1	165	331	3.95	39.1	117	235
2.16	*135*	*404*	*809*	2.76	81.9	246	492	3.36	54.8	164	329	3.96	38.9	117	234
2.17	*134*	*401*	*802*	2.77	81.3	244	488	3.37	54.4	163	326	3.97	38.7	116	232
2.18	*132*	*397*	*794*	2.78	80.8	242	485	3.38	54.1	162	325	3.98	38.5	116	231
2.19	*131*	*393*	*787*	2.79	80.2	240	481	3.39	53.8	161	323	3.99	38.3	115	230
2.20	*130*	*390*	*780*	2.80	79.6	239	477	3.40	53.4	160	321	4.00	38.1	114	229
2.21	*129*	*386*	*772*	2.81	79.0	237	474	3.41	53.1	159	319	4.01	37.9	114	228
2.22	*128*	*383*	*765*	2.82	78.4	235	471	3.42	52.8	158	317	4.02	37.7	113	226
2.23	*126*	*379*	*758*	2.83	77.9	234	467	3.43	52.5	157	315	4.03	37.5	113	225
2.24	*125*	*376*	*752*	2.84	77.3	232	464	3.44	52.2	156	313	4.04	37.3	112	224
2.25	*124*	*372*	*745*	2.85	76.8	230	461	3.45	51.8	156	311	4.05	37.1	111	223
2.26	*123*	*369*	*738*	2.86	76.2	229	457	3.46	51.5	155	309	4.06	37.0	111	222
2.27	*122*	*366*	*732*	2.87	75.7	227	454	3.47	51.2	154	307	4.07	36.8	110	221
2.28	*121*	*363*	*725*	2.88	75.1	225	451	3.48	50.9	153	306	4.08	36.6	110	219
2.29	*120*	*359*	*719*	2.89	74.6	224	448	3.49	50.6	152	304	4.09	36.4	109	218
2.30	*119*	*356*	*712*	2.90	74.1	222	444	3.50	50.3	151	302	4.10	36.2	109	217
2.31	*118*	*353*	*706*	2.91	73.6	221	441	3.51	50.0	150	300	4.11	36.0	108	216
2.32	*117*	*350*	*700*	2.92	73.0	219	438	3.52	49.7	149	298	4.12	35.8	108	215
2.33	*116*	*347*	*694*	2.93	72.5	218	435	3.53	49.4	148	297	4.13	35.7	107	214
2.34	*115*	*344*	*688*	2.94	72.0	216	432	3.54	49.2	147	295	4.14	35.5	106	213
2.35	*114*	*341*	*682*	2.95	71.5	215	429	3.55	48.9	147	293	4.15	35.3	106	212
2.36	*113*	*338*	*676*	2.96	71.0	213	426	3.56	48.6	146	292	4.16	35.1	105	211
2.37	*112*	*335*	*670*	2.97	70.5	212	423	3.57	48.3	145	290	4.17	34.9	105	210
2.38	*111*	*332*	*665*	2.98	70.1	210	420	3.58	48.0	144	288	4.18	34.8	104	209
2.39	*110*	*330*	*659*	2.99	69.6	209	417	3.59	47.7	143	286	4.19	34.6	104	208
2.40	*109*	*327*	*653*	3.00	69.1	207	415	3.60	47.5	142	285	4.20	34.4	103	207
2.41	*108*	*324*	*648*	3.01	68.6	206	412	3.61	47.2	142	283	4.21	34.2	103	205
2.42	*107*	*322*	*643*	3.02	68.2	205	409	3.62	46.9	141	282	4.22	34.1	102	204
2.43	*106*	*319*	*637*	3.03	67.7	203	406	3.63	46.7	140	280	4.23	33.9	102	203
2.44	*105*	*316*	*632*	3.04	67.3	202	404	3.64	46.4	139	278	4.24	33.7	101	202
2.45	*104*	*313*	*627*	3.05	66.8	200	401	3.65	46.1	138	277	4.25	33.6	101	201
2.46	*104*	*311*	*621*	3.06	66.4	199	398	3.66	45.9	138	275	4.26	33.4	100	200
2.47	*103*	*308*	*616*	3.07	65.9	198	395	3.67	45.6	137	274	4.27	33.2	99.7	199
2.48	*102*	*306*	*611*	3.08	65.5	196	393	3.68	45.4	136	272	4.28	33.1	99.2	198
2.49	*101*	*303*	*606*	3.09	65.0	195	390	3.69	45.1	135	271	4.29	32.9	98.8	198
2.50	100	301	601	3.10	64.6	194	388	3.70	44.9	135	269	4.30	32.8	98.3	197
2.51	99.4	298	597	3.11	64.2	193	385	3.71	44.6	134	268	4.31	32.6	97.8	196
2.52	98.6	296	592	3.12	63.8	191	383	3.72	44.4	133	266	4.32	32.4	97.3	195
2.53	97.8	294	587	3.13	63.3	190	380	3.73	44.1	132	265	4.33	32.3	96.8	194
2.54	97.1	291	582	3.14	62.9	189	378	3.74	43.9	132	263	4.34	32.1	96.4	193
2.55	96.3	289	578	3.15	62.5	188	375	3.75	43.6	131	262	4.35	32.0	95.9	192
2.56	95.5	287	573	3.16	62.1	186	373	3.76	43.4	130	260	4.36	31.8	95.5	191
2.57	94.8	284	569	3.17	61.7	185	370	3.77	43.1	129	259	4.37	31.7	95.0	190
2.58	94.0	282	564	3.18	61.3	184	368	3.78	42.9	129	257	4.38	31.5	94.5	189
2.59	93.3	280	560	3.19	60.9	183	366	3.79	42.7	128	256	4.39	31.4	94.1	188
4.40	31.2	93.6	187	5.05	23.3	69.8	140	5.70	17.8	53.5	107	6.35	*14.0*	*42.0*	*84.0*
4.41	31.1	93.2	186	5.06	23.2	69.5	139	5.71	17.8	53.3	107	6.36	*13.9*	*41.8*	*83.7*
4.42	30.9	92.7	185	5.07	23.1	69.2	138	5.72	17.7	53.1	106	6.37	*13.9*	*41.7*	*83.4*
4.43	30.8	92.3	185	5.08	23.0	68.9	138	5.73	17.6	52.9	106	6.38	*13.8*	*41.5*	*83.1*
4.44	30.6	91.8	184	5.09	22.9	68.6	137	5.74	17.6	52.7	105	6.39	*13.8*	*41.4*	*82.8*
4.45	30.5	91.4	183	5.10	22.8	68.3	137	5.75	17.5	52.5	105	6.40	*13.7*	*41.2*	*82.5*
4.46	30.3	91.0	182	5.11	22.7	68.0	136	5.76	17.4	52.3	105	6.41	*13.7*	*41.1*	*82.2*
4.47	30.2	90.5	181	5.12	22.6	67.7	135	5.77	17.4	52.1	104	6.42	*13.6*	*40.9*	*81.9*
4.48	30.0	90.1	180	5.13	22.5	67.4	135	5.78	17.3	51.9	104	6.43	*13.6*	*40.8*	*81.6*

TABLE 6 *Continued*

Diameter of Indenta-tion, mm	Brinell Hardness Number			Diameter of Indenta-tion, mm	Brinell Hardness Number			Diameter of Indenta-tion, mm	Brinell Hardness Number			Diameter of Indenta-tion, mm	Brinell Hardness Number		
	500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load		500-kgf Load	1500-kgf Load	3000-kgf Load
4.49	29.9	89.7	179	5.14	22.4	67.1	134	5.79	17.2	51.7	103	6.44	*13.5*	*40.6*	*81.3*
4.50	29.8	89.3	179	5.15	22.3	66.9	134	5.80	17.2	51.5	103	6.45	*13.5*	*40.5*	*81.0*
4.51	29.6	88.8	178	5.16	22.2	66.6	133	5.81	17.1	51.3	103	6.46	*13.4*	*40.4*	*80.7*
4.52	29.5	88.4	177	5.17	22.1	66.3	133	5.82	17.0	51.1	102	6.47	*13.4*	*40.2*	*80.4*
4.53	29.3	88.0	176	5.18	22.0	66.0	132	5.83	17.0	50.9	102	6.48	*13.4*	*40.1*	*80.1*
4.54	29.2	87.6	175	5.19	21.9	65.8	132	5.84	16.9	50.7	101	6.49	*13.3*	*39.9*	*79.8*
4.55	29.1	87.2	174	5.20	21.8	65.5	131	5.85	16.8	50.5	101	6.50	*13.3*	*39.8*	*79.6*
4.56	28.9	86.8	174	5.21	21.7	65.2	130	5.86	16.8	50.3	101	6.51	*13.2*	*39.6*	*79.3*
4.57	28.8	86.4	173	5.22	21.6	64.9	130	5.87	16.7	50.2	100	6.52	*13.2*	*39.5*	*79.0*
4.58	28.7	86.0	172	5.23	21.6	64.7	129	5.88	16.7	50.0	99.9	6.53	*13.1*	*39.4*	*78.7*
4.59	28.5	85.6	171	5.24	21.5	64.4	129	5.89	16.6	49.8	99.5	6.54	*13.1*	*39.2*	*78.4*
4.60	28.4	85.4	170	5.25	21.4	64.1	128	5.90	16.5	49.6	99.2	6.55	*13.0*	*39.1*	*78.2*
4.61	28.3	84.8	170	5.26	21.3	63.9	128	5.91	16.5	49.4	98.8	6.56	*13.0*	*38.9*	*78.0*
4.62	28.1	84.4	169	5.27	21.2	63.6	127	5.92	16.4	49.2	98.4	6.57	*12.9*	*38.8*	*77.6*
4.63	28.0	84.0	168	5.28	21.1	63.3	127	5.93	16.3	49.0	98.0	6.58	*12.9*	*38.7*	*77.3*
4.64	27.9	83.6	167	5.29	21.0	63.1	126	5.94	16.3	48.8	97.7	6.59	*12.8*	*38.5*	*77.1*
4.65	27.8	83.3	167	5.30	20.9	62.8	126	5.95	16.2	48.7	97.3	6.60	*12.8*	*38.4*	*76.8*
4.66	27.6	82.9	166	5.31	20.9	62.6	125	5.96	16.2	48.5	96.9	6.61	*12.8*	*38.3*	*76.5*
4.67	27.5	82.5	165	5.32	20.8	62.3	125	5.97	16.1	48.3	96.6	6.62	*12.7*	*38.1*	*76.2*
4.68	27.4	82.1	164	5.33	20.7	62.1	124	5.98	16.0	48.1	96.2	6.63	*12.7*	*38.0*	*76.0*
4.69	27.3	81.8	164	5.34	20.6	61.8	124	5.99	16.0	47.9	95.9	6.64	*12.6*	*37.9*	*75.7*
4.70	27.1	81.4	163	5.35	20.5	61.5	123	6.00	*15.9*	47.7	95.5	6.65	*12.6*	*37.7*	*75.4*
4.71	27.0	81.0	162	5.36	20.4	61.3	123	6.01	*15.9*	47.6	95.1	6.66	*12.5*	*37.6*	*75.2*
4.72	26.9	80.7	161	5.37	20.3	61.0	122	6.02	*15.8*	47.4	94.8	6.67	*12.5*	*37.5*	*74.9*
4.73	26.8	80.3	161	5.38	20.3	60.8	122	6.03	*15.7*	47.2	94.4	6.68	*12.4*	*37.3*	*74.7*
4.74	26.6	79.9	160	5.39	20.2	60.6	121	6.04	*15.7*	47.0	94.1	6.69	*12.4*	*37.2*	*74.4*
4.75	26.5	79.6	159	5.40	20.1	60.3	121	6.05	*15.6*	46.8	93.7	6.70	*12.4*	*37.1*	*74.1*
4.76	26.4	79.2	158	5.41	20.0	60.1	120	6.06	*15.6*	46.7	93.4	6.71	*12.3*	*36.9*	*73.9*
4.77	26.3	78.9	158	5.42	19.9	59.8	120	6.07	*15.5*	46.5	93.0	6.72	*12.3*	*36.8*	*73.6*
4.78	26.2	78.5	157	5.43	19.9	59.6	119	6.08	*15.4*	46.3	92.7	6.73	*12.2*	*36.7*	*73.4*
4.79	26.1	78.2	156	5.44	19.8	59.3	119	6.09	*15.4*	46.2	92.3	6.74	*12.2*	*36.6*	*73.1*
4.80	25.9	77.8	156	5.45	19.7	59.1	118	6.10	*15.3*	46.0	92.0	6.75	*12.1*	*36.4*	*72.8*
4.81	25.8	77.5	155	5.46	19.6	58.9	118	6.11	*15.3*	45.8	91.7	6.76	*12.1*	*36.3*	*72.6*
4.82	25.7	77.1	154	5.47	19.5	58.6	117	6.12	*15.2*	45.7	91.3	6.77	*12.1*	*36.2*	*72.3*
4.83	25.6	76.8	154	5.48	19.5	58.4	117	6.13	*15.2*	45.5	91.0	6.78	*12.0*	*36.0*	*72.1*
4.84	25.5	76.4	153	5.49	19.4	58.2	116	6.14	*15.1*	45.3	90.6	6.79	*12.0*	*35.9*	*71.8*
4.85	25.4	76.1	152	5.50	19.3	57.9	116	6.15	*15.1*	45.2	90.3	6.80	*11.9*	*35.8*	*71.6*
4.86	25.3	75.8	152	5.51	19.2	57.7	115	6.16	*15.0*	45.0	90.0	6.81	*11.9*	*35.7*	*71.3*
4.87	25.1	75.4	151	5.52	19.2	57.5	115	6.17	*14.9*	44.8	89.6	6.82	*11.8*	*35.5*	*71.1*
4.88	25.0	75.1	150	5.53	19.1	57.2	114	6.18	*14.9*	44.7	89.3	6.83	*11.8*	*35.4*	*70.8*
4.89	24.9	74.8	150	5.54	19.0	57.0	114	6.19	*14.8*	44.5	89.0	6.84	*11.8*	*35.3*	*70.6*
4.90	24.8	74.4	149	5.55	18.9	56.8	114	6.20	*14.7*	44.3	88.7	6.85	*11.7*	*35.2*	*70.4*
4.91	24.7	74.1	148	5.56	18.9	56.6	113	6.21	*14.7*	44.2	88.3	6.86	*11.7*	*35.1*	*70.1*
4.92	24.6	73.8	148	5.57	18.8	56.3	113	6.22	*14.7*	44.0	88.0	6.87	*11.6*	*34.9*	*69.9*
4.93	24.5	73.5	147	5.58	18.7	56.1	112	6.23	*14.6*	43.8	87.7	6.88	*11.6*	*34.8*	*69.6*
4.94	24.4	73.2	146	5.59	18.6	55.9	112	6.24	*14.6*	43.7	87.4	6.89	*11.6*	*34.7*	*69.4*
4.95	24.3	72.8	146	5.60	18.6	55.7	111	6.25	*14.5*	43.5	87.1	6.90	*11.5*	*34.6*	*69.2*
4.96	24.2	72.5	145	5.61	18.5	55.5	111	6.26	*14.5*	43.4	86.7	6.91	*11.5*	*34.5*	*68.9*
4.97	24.1	72.2	144	5.62	18.4	55.2	110	6.27	*14.4*	43.2	86.4	6.92	*11.4*	*34.3*	*68.7*
4.98	24.0	71.9	144	5.63	18.3	55.0	110	6.28	*14.4*	43.1	86.1	6.93	*11.4*	*34.2*	*68.4*
4.99	23.9	71.6	143	5.64	18.3	54.8	110	6.29	*14.3*	42.9	85.8	6.94	*11.4*	*34.1*	*68.2*
5.00	23.8	71.3	143	5.65	18.2	54.6	109	6.30	*14.2*	42.7	85.5	6.95	*11.3*	*34.0*	*68.0*
5.01	23.7	71.0	142	5.66	18.1	54.4	109	6.31	*14.2*	42.6	85.2	6.96	*11.3*	*33.9*	*67.7*
5.02	23.6	70.7	141	5.67	18.1	54.2	108	6.32	*14.1*	42.4	84.9	6.97	*11.3*	*33.8*	*67.5*
5.03	23.5	70.4	141	5.68	18.0	54.0	108	6.33	*14.1*	42.3	84.6	6.98	*11.2*	*33.6*	*67.3*
5.04	23.4	70.1	140	5.69	17.9	53.7	107	6.34	*14.0*	42.1	84.3	6.99	*11.2*	*33.5*	*67.0*

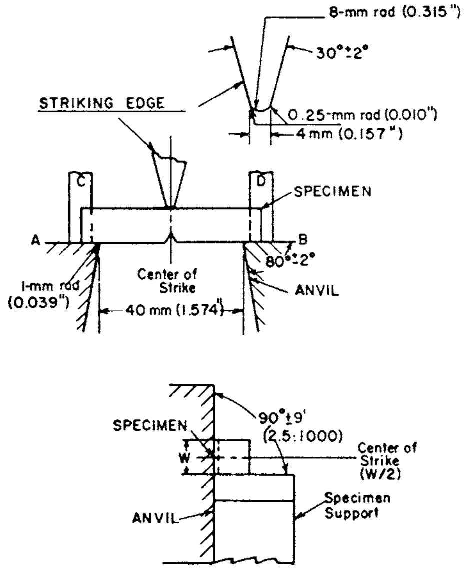
[A] Prepared by the Engineering Mechanics Section, Institute for Standards Technology.

21. Apparatus

21.1 *Testing Machines*:

21.1.1 A Charpy impact machine is one in which a notched specimen is broken by a single blow of a freely swinging pendulum. The pendulum is released from a fixed height. Since the height to which the pendulum is raised prior to its swing, and the mass of the pendulum are known, the energy of the blow is predetermined. A means is provided to indicate the energy absorbed in breaking the specimen.

21.1.2 The other principal feature of the machine is a fixture (See Fig. 10) designed to support a test specimen as a simple beam at a precise location. The fixture is arranged so that the



All dimensional tolerances shall be ±0.05 mm (0.002 in.) unless otherwise specified.

NOTE 1—A shall be parallel to B within 2:1000 and coplanar with B within 0.05 mm (0.002 in.).

NOTE 2—C shall be parallel to D within 20:1000 and coplanar with D within 0.125 mm (0.005 in.).

NOTE 3—Finish on unmarked parts shall be 4 µm (125 µin.).

FIG. 10 Charpy (Simple-Beam) Impact Test

notched face of the specimen is vertical. The pendulum strikes the other vertical face directly opposite the notch. The dimensions of the specimen supports and striking edge shall conform to Fig. 10.

21.1.3 Charpy machines used for testing steel generally have capacities in the 220 to 300 ft·lbf (300 to 400 J) energy range. Sometimes machines of lesser capacity are used; however, the capacity of the machine should be substantially in excess of the absorbed energy of the specimens (see Test Methods E 23). The linear velocity at the point of impact should be in the range of 16 to 19 ft/s (4.9 to 5.8 m/s).

21.2 *Temperature Media*:

21.2.1 For testing at other than room temperature, it is necessary to condition the Charpy specimens in media at controlled temperatures.

21.2.2 Low temperature media usually are chilled fluids (such as water, ice plus water, dry ice plus organic solvents, or liquid nitrogen) or chilled gases.

21.2.3 Elevated temperature media are usually heated liquids such as mineral or silicone oils. Circulating air ovens may be used.

21.3 *Handling Equipment*—Tongs, especially adapted to fit the notch in the impact specimen, normally are used for removing the specimens from the medium and placing them on the anvil (refer to Test Methods E 23). In cases where the machine fixture does not provide for automatic centering of the test specimen, the tongs may be precision machined to provide centering.

22. Sampling and Number of Specimens

22.1 *Sampling*:

22.1.1 Test location and orientation should be addressed by the specifications. If not, for wrought products, the test location shall be the same as that for the tensile specimen and the orientation shall be longitudinal with the notch perpendicular to the major surface of the product being tested.

22.1.2 *Number of Specimens*.

22.1.2.1 A Charpy impact test consists of all specimens taken from a single test coupon or test location.

22.1.2.2 When the specification calls for a minimum average test result, three specimens shall be tested.

22.1.2.3 When the specification requires determination of a transition temperature, eight to twelve specimens are usually needed.

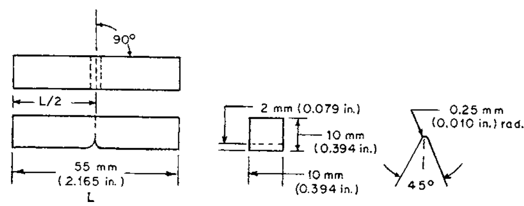
22.2 *Type and Size*:

22.2.1 Use a standard full size Charpy V-notch specimen (Type A) as shown in Fig. 11, except as allowed in 22.2.2.

22.2.2 *Subsized Specimens*.

22.2.2.1 For flat material less than 7⁄16 in. (11 mm) thick, or when the absorbed energy is expected to exceed 80 % of full scale, use standard subsize test specimens.

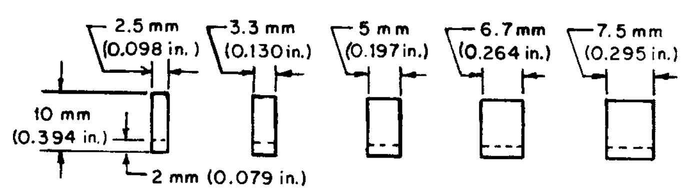
22.2.2.2 For tubular materials tested in the transverse direction, where the relationship between diameter and wall thickness does not permit a standard full size specimen, use standard



NOTE 1—Permissible variations shall be as follows:

Notch length to edge	90 ±2°
Adjacent sides shall be at	90° ± 10 min
Cross-section dimensions	±0.075 mm (±0.003 in.)
Length of specimen (L)	+ 0, − 2.5 mm (+ 0, − 0.100 in.)
Centering of notch (L/2)	±1 mm (±0.039 in.)
Angle of notch	±1°
Radius of notch	±0.025 mm (±0.001 in.)
Notch depth	±0.025 mm (±0.001 in.)
Finish requirements	2 µm (63 µin.) on notched surface and opposite face; 4 µm (125 µin.) on other two surfaces

(*a*) Standard Full Size Specimen



NOTE 2—On subsize specimens, all dimensions and tolerances of the standard specimen remain constant with the exception of the width, which varies as shown above and for which the tolerance shall be ±1 %.

(*b*) Standard Subsize Specimens

FIG. 11 Charpy (Simple Beam) Impact Test Specimens

subsize test specimens or standard size specimens containing outer diameter (OD) curvature as follows:

(1) Standard size specimens and subsize specimens may contain the original OD surface of the tubular product as shown in Fig. 12. All other dimensions shall comply with the requirements of Fig. 11.

NOTE 14—For materials with toughness levels in excess of about 50 ft-lbs, specimens containing the original OD surface may yield values in excess of those resulting from the use of conventional Charpy specimens.

22.2.2.3 If a standard full-size specimen cannot be prepared, the largest feasible standard subsize specimen shall be prepared. The specimens shall be machined so that the specimen does not include material nearer to the surface than 0.020 in. (0.5 mm).

22.2.2.4 Tolerances for standard subsize specimens are shown in Fig. 11. Standard subsize test specimen sizes are: 10 × 7.5 mm, 10 × 6.7 mm, 10 × 5 mm, 10 × 3.3 mm, and 10 × 2.5 mm.

22.2.2.5 Notch the narrow face of the standard subsize specimens so that the notch is perpendicular to the 10 mm wide face.

22.3 *Notch Preparation*—The machining of the notch is critical, as it has been demonstrated that extremely minor variations in notch radius and profile, or tool marks at the bottom of the notch may result in erratic test data. (See Annex A5).

23. Calibration

23.1 *Accuracy and Sensitivity*—Calibrate and adjust Charpy impact machines in accordance with the requirements of Test Methods E 23.

24. Conditioning—Temperature Control

24.1 When a specific test temperature is required by the specification or purchaser, control the temperature of the heating or cooling medium within ±2°F (1°C) because the effect of variations in temperature on Charpy test results can be very great.

NOTE 15—For some steels there may not be a need for this restricted temperature, for example, austenitic steels.

NOTE 16—Because the temperature of a testing laboratory often varies from 60 to 90°F (15 to 32°C) a test conducted at "room temperature" might be conducted at any temperature in this range.

25. Procedure

25.1 *Temperature*:

25.1.1 Condition the specimens to be broken by holding them in the medium at test temperature for at least 5 min in liquid media and 30 min in gaseous media.

25.1.2 Prior to each test, maintain the tongs for handling test specimens at the same temperature as the specimen so as not to affect the temperature at the notch.

25.2 *Positioning and Breaking Specimens*:

25.2.1 Carefully center the test specimen in the anvil and release the pendulum to break the specimen.

25.2.2 If the pendulum is not released within 5 s after removing the specimen from the conditioning medium, do not break the specimen. Return the specimen to the conditioning medium for the period required in 25.1.1.

25.3 *Recovering Specimens*—In the event that fracture appearance or lateral expansion must be determined, recover the matched pieces of each broken specimen before breaking the next specimen.

25.4 *Individual Test Values*:

25.4.1 *Impact energy*— Record the impact energy absorbed to the nearest ft·lbf (J).

25.4.2 *Fracture Appearance*:

25.4.2.1 Determine the percentage of shear fracture area by any of the following methods:

(1) Measure the length and width of the brittle portion of the fracture surface, as shown in Fig. 13 and determine the percent shear area from either Table 7 or Table 8 depending on the units of measurement.

(2) Compare the appearance of the fracture of the specimen with a fracture appearance chart as shown in Fig. 14.

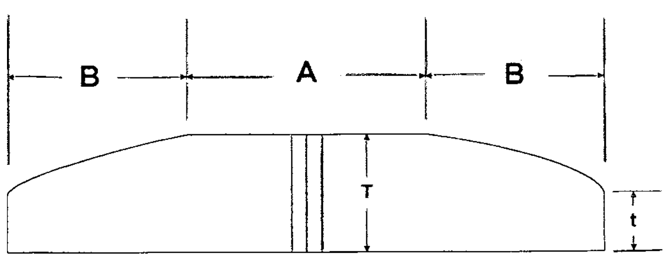
(3) Magnify the fracture surface and compare it to a precalibrated overlay chart or measure the percent shear fracture area by means of a planimeter.

(4) Photograph the fractured surface at a suitable magnification and measure the percent shear fracture area by means of a planimeter.

25.4.2.2 Determine the individual fracture appearance values to the nearest 5 % shear fracture and record the value.

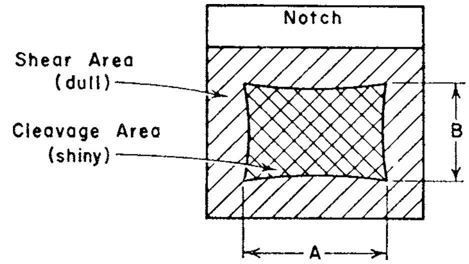
25.4.3 *Lateral Expansion*:

25.4.3.1 Lateral expansion is the increase in specimen width, measured in thousandths of an inch (mils), on the



Dimension	Description	Requirement
A	Machined Surface	28 mm Minimum
B	Original OD Surface	13.5 mm Maximum
T	Specimen Thickness	Figure 11
t	End Thickness	½ T Minimum

FIG. 12 Tubular Impact Specimen Containing Original OD Surface



NOTE 1—Measure average dimensions *A* and *B* to the nearest 0.02 in. or 0.5 mm.
NOTE 2—Determine the percent shear fracture using Table 7 or Table 8.

FIG. 13 Determination of Percent Shear Fracture

TABLE 7 Percent Shear for Measurements Made in Inches

NOTE 1—Since this table is set up for finite measurements or dimensions *A* and *B*, 100% shear is to be reported when either *A* or *B* is zero.

Dimension *B*, in.	Dimension *A*, in.																
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40
0.05	98	96	95	94	94	93	92	91	90	90	89	88	87	86	85	85	84
0.10	96	92	90	89	87	85	84	82	81	79	77	76	74	73	71	69	68
0.12	95	90	88	86	85	83	81	79	77	75	73	71	69	67	65	63	61
0.14	94	89	86	84	82	80	77	75	73	71	68	66	64	62	59	57	55
0.16	94	87	85	82	79	77	74	72	69	67	64	61	59	56	53	51	48
0.18	93	85	83	80	77	74	72	68	65	62	59	56	54	51	48	45	42
0.20	92	84	81	77	74	72	68	65	61	58	55	52	48	45	42	39	36
0.22	91	82	79	75	72	68	65	61	57	54	50	47	43	40	36	33	29
0.24	90	81	77	73	69	65	61	57	54	50	46	42	38	34	30	27	23
0.26	90	79	75	71	67	62	58	54	50	46	41	37	33	29	25	20	16
0.28	89	77	73	68	64	59	55	50	46	41	37	32	28	23	18	14	10
0.30	88	76	71	66	61	56	52	47	42	37	32	27	23	18	13	9	3
0.31	88	75	70	65	60	55	50	45	40	35	30	25	20	18	10	5	0

TABLE 8 Percent Shear for Measurements Made in Millimetres

NOTE 1—Since this table is set up for finite measurements or dimensions *A* and *B*, 100% shear is to be reported when either *A* or *B* is zero.

Dimension *B*, mm	Dimension *A*, mm																		
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10
1.0	99	98	98	97	96	96	95	94	94	93	92	92	91	91	90	89	89	88	88
1.5	98	97	96	95	94	93	92	92	91	90	89	88	87	86	85	84	83	82	81
2.0	98	96	95	94	92	91	90	89	88	86	85	84	82	81	80	79	77	76	75
2.5	97	95	94	92	91	89	88	86	84	83	81	80	78	77	75	73	72	70	69
3.0	96	94	92	91	89	87	85	83	81	79	77	76	74	72	70	68	66	64	62
3.5	96	93	91	89	87	85	82	80	78	76	74	72	69	67	65	63	61	58	56
4.0	95	92	90	88	85	82	80	77	75	72	70	67	65	62	60	57	55	52	50
4.5	94	92	89	86	83	80	77	75	72	69	66	63	61	58	55	52	49	46	44
5.0	94	91	88	85	81	78	75	72	69	66	62	59	56	53	50	47	44	41	37
5.5	93	90	86	83	79	76	72	69	66	62	59	55	52	48	45	42	38	35	31
6.0	92	89	85	81	77	74	70	66	62	59	55	51	47	44	40	36	33	29	25
6.5	92	88	84	80	76	72	67	63	59	55	51	47	43	39	35	31	27	23	19
7.0	91	87	82	78	74	69	65	61	56	52	47	43	39	34	30	26	21	17	12
7.5	91	86	81	77	72	67	62	58	53	48	44	39	34	30	25	20	16	11	6
8.0	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0

compression side, opposite the notch of the fractured Charpy V-notch specimen as shown in Fig. 15.

25.4.3.2 Examine each specimen half to ascertain that the protrusions have not been damaged by contacting the anvil, machine mounting surface, and so forth. Discard such samples since they may cause erroneous readings.

25.4.3.3 Check the sides of the specimens perpendicular to the notch to ensure that no burrs were formed on the sides during impact testing. If burrs exist, remove them carefully by rubbing on emery cloth or similar abrasive surface, making sure that the protrusions being measured are not rubbed during the removal of the burr.

25.4.3.4 Measure the amount of expansion on each side of each half relative to the plane defined by the undeformed portion of the side of the specimen using a gauge similar to that shown in Fig. 16 and Fig. 17.

25.4.3.5 Since the fracture path seldom bisects the point of maximum expansion on both sides of a specimen, the sum of the larger values measured for each side is the value of the test. Arrange the halves of one specimen so that compression sides

FIG. 14 Fracture Appearance Charts and Percent Shear Fracture Comparator

FIG. 15 Halves of Broken Charpy V-Notch Impact Specimen Joined for the Measurement of Lateral Expansion, Dimension *A*

are facing each other. Using the gauge, measure the protrusion on each half specimen, ensuring that the same side of the specimen is measured. Measure the two broken halves individually. Repeat the procedure to measure the protrusions on the opposite side of the specimen halves. The larger of the two values for each side is the expansion of that side of the specimen.

25.4.3.6 Measure the individual lateral expansion values to the nearest mil (0.025 mm) and record the values.

25.4.3.7 With the exception described as follows, any specimen that does not separate into two pieces when struck by a single blow shall be reported as unbroken. If the specimen can be separated by force applied by bare hands, the specimen may be considered as having been separated by the blow.

26. Interpretation of Test Result

26.1 When the acceptance criterion of any impact test is specified to be a minimum average value at a given temperature, the test result shall be the average (arithmetic mean) of the individual test values of three specimens from one test location.

26.1.1 When a minimum average test result is specified:

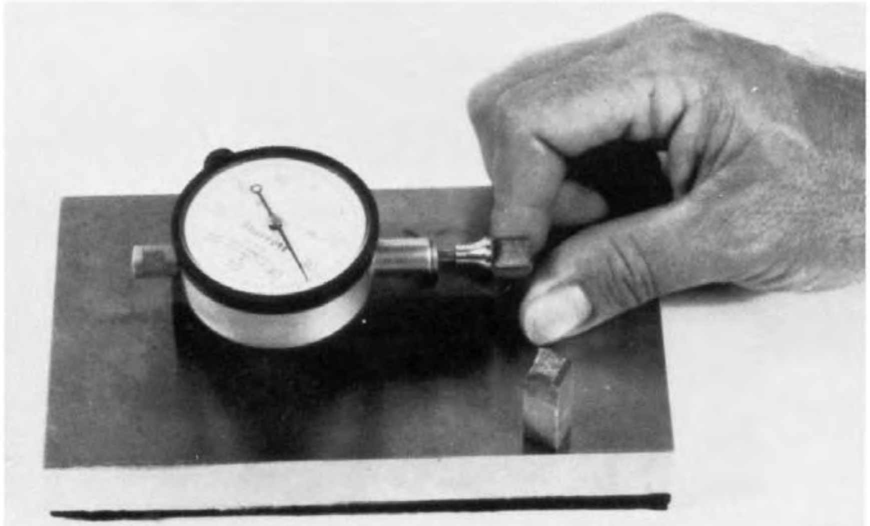
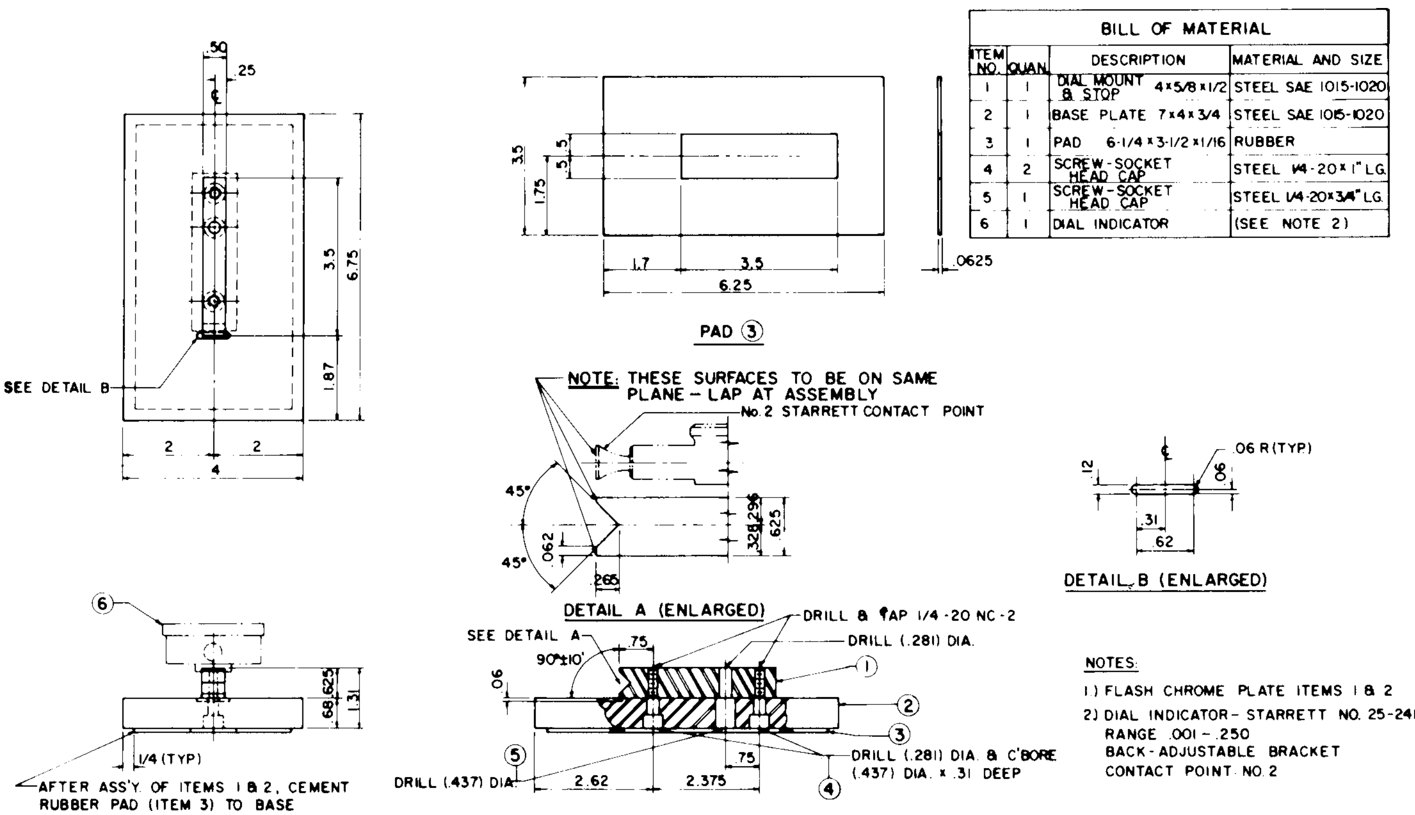


FIG. 16 Lateral Expansion Gauge for Charpy Impact Specimens



ITEM NO.	QUAN.	DESCRIPTION	MATERIAL AND SIZE
1	1	DIAL MOUNT & STOP 4 x 5/8 x 1/2	STEEL SAE 1015-1020
2	1	BASE PLATE 7 x 4 x 3/4	STEEL SAE 1015-1020
3	1	PAD 6-1/4 x 3-1/2 x 1/16	RUBBER
4	2	SCREW - SOCKET HEAD CAP	STEEL 1/4 - 20 x 1" LG.
5	1	SCREW - SOCKET HEAD CAP	STEEL 1/4 - 20 x 3/4" LG.
6	1	DIAL INDICATOR	(SEE NOTE 2)

FIG. 17 Assembly and Details for Lateral Expansion Gauge

26.1.1.1 The test result is acceptable when all of the below are met:

(1) The test result equals or exceeds the specified minimum average (given in the specification),

(2) The individual test value for not more than one specimen measures less than the specified minimum average, and

(3) The individual test value for any specimen measures not less than two-thirds of the specified minimum average.

26.1.1.2 If the acceptance requirements of 26.1.1.1 are not met, perform one retest of three additional specimens from the same test location. Each individual test value of the retested specimens shall be equal to or greater than the specified minimum average value.

26.2 *Test Specifying a Minimum Transition Temperature*:

26.2.1 *Definition of Transition Temperature*—For specification purposes, the transition temperature is the temperature at which the designated material test value equals or exceeds a specified minimum test value.

26.2.2 *Determination of Transition Temperature*:

26.2.2.1 Break one specimen at each of a series of temperatures above and below the anticipated transition temperature using the procedures in Section 25. Record each test temperature to the nearest 1°F (0.5°C).

26.2.2.2 Plot the individual test results (ft·lbf or percent shear) as the ordinate versus the corresponding test temperature as the abscissa and construct a best-fit curve through the plotted data points.

26.2.2.3 If transition temperature is specified as the temperature at which a test value is achieved, determine the temperature at which the plotted curve intersects the specified test value by graphical interpolation (extrapolation is not permitted). Record this transition temperature to the nearest 5°F (3°C). If the tabulated test results clearly indicate a transition temperature lower than specified, it is not necessary to plot the data. Report the lowest test temperature for which test value exceeds the specified value.

26.2.2.4 Accept the test result if the determined transition temperature is equal to or lower than the specified value.

26.2.2.5 If the determined transition temperature is higher than the specified value, but not more than 20°F (12°C) higher than the specified value, test sufficient samples in accordance with Section 25 to plot two additional curves. Accept the test results if the temperatures determined from both additional tests are equal to or lower than the specified value.

26.3 When subsize specimens are permitted or necessary, or both, modify the specified test requirement according to Table 9 or test temperature according to ASME Boiler and Pressure Vessel Code, Table UG-84.2, or both. Greater energies or lower test temperatures may be agreed upon by purchaser and supplier.

27. Records

27.1 The test record should contain the following information as appropriate:

27.1.1 Full description of material tested (that is, specification number, grade, class or type, size, heat number).

27.1.2 Specimen orientation with respect to the material axis.

27.1.3 Specimen size.

27.1.4 Test temperature and individual test value for each specimen broken, including initial tests and retests.

27.1.5 Test results.

27.1.6 Transition temperature and criterion for its determination, including initial tests and retests.

28. Report

28.1 The specification should designate the information to be reported.

29. Keywords

29.1 bend test; Brinell hardness; Charpy impact test; elongation; FATT (Fracture Appearance Transition Temperature); hardness test; portable hardness; reduction of area; Rockwell hardness; tensile strength; tension test; yield strength

TABLE 9 Charpy V-Notch Test Acceptance Criteria for Various Sub-Size Specimens

Full Size, 10 by 10 mm		¾ Size, 10 by 7.5 mm		⅔ Size, 10 by 6.7 mm		½ Size, 10 by 5 mm		⅓ Size, 10 by 3.3 mm		¼ Size, 10 by 2.5 mm	
ft·lbf	[J]	ft·lbf	[J]	ft·lbf	[J]	ft·lbf	[J]	ft·lbf	[J]	ft·lbf	[J]
40	[54]	30	[41]	27	[37]	20	[27]	13	[18]	10	[14]
35	[48]	26	[35]	23	[31]	18	[24]	12	[16]	9	[12]
30	[41]	22	[30]	20	[27]	15	[20]	10	[14]	8	[11]
25	[34]	19	[26]	17	[23]	12	[16]	8	[11]	6	[8]
20	[27]	15	[20]	13	[18]	10	[14]	7	[10]	5	[7]
16	[22]	12	[16]	11	[15]	8	[11]	5	[7]	4	[5]
15	[20]	11	[15]	10	[14]	8	[11]	5	[7]	4	[5]
13	[18]	10	[14]	9	[12]	6	[8]	4	[5]	3	[4]
12	[16]	9	[12]	8	[11]	6	[8]	4	[5]	3	[4]
10	[14]	8	[11]	7	[10]	5	[7]	3	[4]	2	[3]
7	[10]	5	[7]	5	[7]	4	[5]	2	[3]	2	[3]

ANNEXES

(Mandatory Information)

A1. STEEL BAR PRODUCTS

A1.1 Scope

A1.1.1 This supplement delineates only those details which are peculiar to hot-rolled and cold-finished steel bars and are not covered in the general section of these test methods.

A1.2 Orientation of Test Specimens

A1.2.1 Carbon and alloy steel bars and bar-size shapes, due to their relatively small cross-sectional dimensions, are customarily tested in the longitudinal direction. In special cases where size permits and the fabrication or service of a part justifies testing in a transverse direction, the selection and location of test or tests are a matter of agreement between the manufacturer and the purchaser.

A1.3 Tension Test

A1.3.1 *Carbon Steel Bars*—Carbon steel bars are not commonly specified to tensile requirements in the as-rolled condition for sizes of rounds, squares, hexagons, and octagons under ½ in. (13 mm) in diameter or distance between parallel faces nor for other bar-size sections, other than flats, less than 1 in.^{2} (645 mm^2) in cross-sectional area.

A1.3.2 *Alloy Steel Bars*—Alloy steel bars are usually not tested in the as-rolled condition.

A1.3.3 When tension tests are specified, the practice for selecting test specimens for hot-rolled and cold-finished steel bars of various sizes shall be in accordance with Table A1.1, unless otherwise specified in the product specification.

A1.4 Bend Test

A1.4.1 When bend tests are specified, the recommended practice for hot-rolled and cold-finished steel bars shall be in accordance with Table A1.2.

A1.5 Hardness Test

A1.5.1 *Hardness Tests on Bar Products*—flats, rounds, squares, hexagons and octagons—is conducted on the surface after a minimum removal of 0.015 in. to provide for accurate hardness penetration.

TABLE A1.1 Practices for Selecting Tension Test Specimens for Steel Bar Products

NOTE 1—For bar sections where it is difficult to determine the cross-sectional area by simple measurement, the area in square inches may be calculated by dividing the weight per linear inch of specimen in pounds by 0.2833 (weight of 1 in.^{3} of steel) or by dividing the weight per linear foot of specimen by 3.4 (weight of steel 1 in. square and 1 ft long).

Thickness, in. (mm)	Width, in. (mm)	Hot-Rolled Bars	Cold-Finished Bars
		Flats	
Under ⅝ (16)	Up to 1½ (38), incl	Full section by 8-in. (200-mm) gauge length (Fig. 3).	Mill reduced section to 2-in. (50-mm) gauge length and approximately 25% less than test specimen width.
	Over 1½ (38)	Full section, or mill to 1½ in. (38 mm) wide by 8-in. (200-mm) gauge length (Fig. 3).	Mill reduced section to 2-in. gauge length and 1½ in. wide.
⅝ to 1½ (16 to 38), excl	Up to 1½ (38), incl	Full section by 8-in. gauge length or machine standard ½ by 2-in. (13 by 50-mm) gauge length specimen from center of section (Fig. 4).	Mill reduced section to 2-in. (50-mm) gauge length and approximately 25% less than test specimen width or machine standard ½ by 2-in. (13 by 50-mm) gauge length specimen from center of section (Fig. 4).
	Over 1½ (38)	Full section, or mill 1½ in. (38 mm) width by 8-in. (200-mm) gauge length (Fig. 3) or machine standard ½ by 2-in. gauge (13 by 50-mm) gauge length specimen from midway between edge and center of section (Fig. 4).	Mill reduced section to 2-in. gauge length and 1½ in. wide or machine standard ½ by 2-in. gauge length specimen from midway between edge and center of section (Fig. 4).
1½ (38) and over		Full section by 8-in. (200-mm) gauge length, or machine standard ½ by 2-in. (13 by 50-mm) gauge length specimen from midway between surface and center (Fig. 4).	Machine standard ½ by 2-in. (13 by 50-mm) gauge length specimen from midway between surface and center (Fig. 4).

Diameter or Distance Between Parallel Faces, in. (mm)	Hot-Rolled Bars	Cold-Finished Bars
	Rounds, Squares, Hexagons, and Octagons	
Under ⅝	Full section by 8-in. (200-mm) gauge length or machine to subsize specimen (Fig. 4).	Machine to sub-size specimen (Fig. 4).
⅝ to 1½ (16 to 38), excl	Full section by 8-in. (200-mm) gauge length or machine standard ½ in. by 2-in. (13 by 50-mm) gauge length specimen from center of section (Fig. 4).	Machine standard ½ in. by 2-in. gauge length specimen from center of section (Fig. 4).
1½ (38) and over	Full section by 8-in. (200-mm) gauge length or machine standard ½ in. by 2-in. (13 by 50-mm) gauge length specimen from midway between surface and center of section (Fig. 4).	Machine standard ½ in. by 2-in. (13 by 50-mm gauge length specimen from midway between surface and center of section (Fig. 4)).
	Other Bar-Size Sections	
All sizes	Full section by 8-in. (200-mm) gauge length or prepare test specimen 1½ in. (38 mm) wide (if possible) by 8-in. (200-mm) gauge length.	Mill reduced section to 2-in. (50-mm) gauge length and approximately 25% less than test specimen width.

TABLE A1.2 Recommended Practice for Selecting Bend Test Specimens for Steel Bar Products

NOTE 1—The length of all specimens is to be not less than 6 in. (150 mm).
NOTE 2—The edges of the specimen may be rounded to a radius not exceeding 1⁄16 in. (1.6 mm).

Thickness, in. (mm)	Width, in. (mm)	Recommended Size
	Flats	
Up to ½ (13), incl	Up to ¾ (19), incl	Full section.
	Over ¾ (19)	Full section or machine to not less than ¾ in. (19 mm) in width by thickness of specimen.
Over ½ (13)	All	Full section or machine to 1 by ½ in. (25 by 13 mm) specimen from midway between center and surface.

Diameter or Distance Between Parallel Faces, in. (mm)	Recommended Size
Rounds, Squares, Hexagons, and Octagons	
Up to 1½ (38), incl	Full section.
Over 1½ (38)	Machine to 1 by ½-in. (25 by 13-mm) specimen from midway between center and surface.

A2. STEEL TUBULAR PRODUCTS

A2.1 Scope

A2.1.1 This supplement covers test specimens and test methods that are applicable to tubular products and are not covered in the general section of Test Methods and Definitions A 370.

A2.1.2 Tubular shapes covered by this specification include, round, square, rectangular, and special shapes.

A2.2 Tension Test

A2.2.1 *Full-Size Longitudinal Test Specimens*:

A2.2.1.1 As an alternative to the use of longitudinal strip test specimens or longitudinal round test specimens, tension test specimens of full-size tubular sections are used, provided that the testing equipment has sufficient capacity. Snug-fitting metal plugs should be inserted far enough in the end of such tubular specimens to permit the testing machine jaws to grip the specimens properly without crushing. A design that may be used for such plugs is shown in Fig. A2.1. The plugs shall not extend into that part of the specimen on which the elongation is measured (Fig. A2.1). Care should be exercised to see that insofar as practicable, the load in such cases is applied axially. The length of the full-section specimen depends on the gauge length prescribed for measuring the elongation.

A2.2.1.2 Unless otherwise required by the product specification, the gauge length is 2 in. or 50 mm, except that for tubing having an outside diameter of ⅜ in. (9.5 mm) or less, it is customary for a gauge length equal to four times the outside diameter to be used when elongation comparable to that obtainable with larger test specimens is required.

A2.2.1.3 To determine the cross-sectional area of the full-section specimen, measurements shall be recorded as the average or mean between the greatest and least measurements of the outside diameter and the average or mean wall thickness, to the nearest 0.001 in. (0.025 mm) and the cross-sectional area is determined by the following equation:

$$A = 3.1416t\,(D - t) \tag{A2.1}$$

where:

A = sectional area, in.^{2}
D = outside diameter, in., and
t = thickness of tube wall, in.

NOTE A2.1—There exist other methods of cross-sectional area determination, such as by weighing of the specimens, which are equally accurate or appropriate for the purpose.

A2.2.2 *Longitudinal Strip Test Specimens*:

A2.2.2.1 As an alternative to the use of full-size longitudinal test specimens or longitudinal round test specimens, longitudinal strip test specimens, obtained from strips cut from the tubular product as shown in Fig. A2.2 and machined to the dimensions shown in Fig. A2.3 are used. For welded structural tubing, such test specimens shall be from a location at least 90° from the weld; for other welded tubular products, such test specimens shall be from a location approximately 90° from the weld. Unless otherwise required by the product specification, the gauge length is 2 in. or 50 mm. The test specimens shall be tested using grips that are flat or have a surface contour corresponding to the curvature of the tubular product, or the ends of the test specimens shall be flattened without heating prior to the test specimens being tested using flat grips. The test specimen shown as specimen no. 4 in Fig. 3 shall be used, unless the capacity of the testing equipment or the dimensions and nature of the tubular product to be tested makes the use of specimen nos. 1, 2, or 3 necessary.

NOTE A2.2—An exact formula for calculating the cross-sectional area of specimens of the type shown in Fig. A2.3 taken from a circular tube is given in Test Methods E 8 or E 8M.

A2.2.2.2 The width should be measured at each end of the gauge length to determine parallelism and also at the center. The thickness should be measured at the center and used with the center measurement of the width to determine the cross-sectional area. The center width dimension should be recorded to the nearest 0.005 in. (0.127 mm), and the thickness measurement to the nearest 0.001 in.

A2.2.3 *Transverse Strip Test Specimens*:

A2.2.3.1 In general, transverse tension tests are not recommended for tubular products, in sizes smaller than 8 in. in

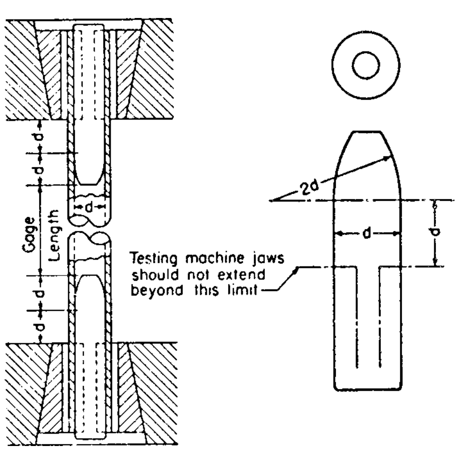
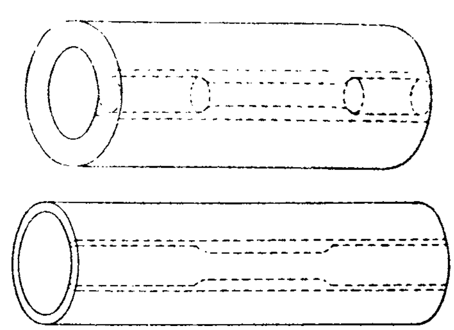
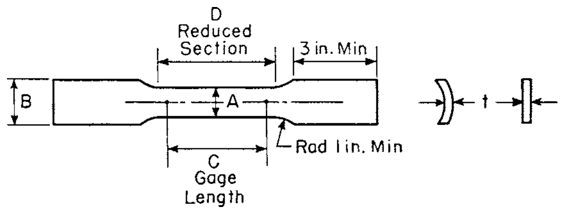


FIG. A2.1 Metal Plugs for Testing Tubular Specimens, Proper Location of Plugs in Specimen and of Specimen in Heads of Testing Machine



NOTE 1—The edges of the blank for the specimen shall be cut parallel to each other.

FIG. A2.2 Location of Longitudinal Tension–Test Specimens in Rings Cut from Tubular Products



DIMENSIONS

Specimen No.	Dimensions, in.			
	A	*B*	*C*	*D*
1	½ ± 0.015	11/16 approximately	2 ± 0.005	2¼ min
2	¾ ± 0.031	1 approximately	2 ± 0.005	2¼ min
			4 ± 0.005	4½ min
3	1± 0.062	1½ approximately	2 ± 0.005	2¼ min
			4 ± 0.005	4½ min
4	1½ ± ⅛	2 approximately	2 ± 0.010	2¼ min
			4 ± 0.015	4½ min
			8 ± 0.020	9 min

NOTE 1—Cross-sectional area may be calculated by multiplying *A* and *t*.

NOTE 2—The dimension *t* is the thickness of the test specimen as provided for in the applicable material specifications.

NOTE 3—The reduced section shall be parallel within 0.010 in. and may have a gradual taper in width from the ends toward the center, with the ends not more than 0.010 in. wider than the center.

NOTE 4—The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in.

NOTE 5—Metric equivalent: 1 in. = 25.4 mm.

NOTE 6—Specimens with sides parallel throughout their length are permitted, except for referee testing, provided: (*a*) the above tolerances are used; (*b*) an adequate number of marks are provided for determination of elongation; and (*c*) when yield strength is determined, a suitable extensometer is used. If the fracture occurs at a distance of less than 2*A* from the edge of the gripping device, the tensile properties determined may not be representative of the material. If the properties meet the minimum requirements specified, no further testing is required, but if they are less than the minimum requirements, discard the test and retest.

FIG. A2.3 Dimensions and Tolerances for Longitudinal Strip Tension Test Specimens for Tubular Products

nominal diameter. When required, transverse tension test specimens may be taken from rings cut from ends of tubes or pipe as shown in Fig. A2.4. Flattening of the specimen may be done either after separating it from the tube as in Fig. A2.4 (*a*), or before separating it as in Fig. A2.4 (*b*), and may be done hot or cold; but if the flattening is done cold, the specimen may subsequently be normalized. Specimens from tubes or pipe for which heat treatment is specified, after being flattened either hot or cold, shall be given the same treatment as the tubes or pipe. For tubes or pipe having a wall thickness of less than ¾ in. (19 mm), the transverse test specimen shall be of the form and dimensions shown in Fig. A2.5 and either or both surfaces may be machined to secure uniform thickness. Specimens for transverse tension tests on welded steel tubes or pipe to determine strength of welds, shall be located perpendicular to the welded seams with the weld at about the middle of their length.

A2.2.3.2 The width should be measured at each end of the gauge length to determine parallelism and also at the center. The thickness should be measured at the center and used with the center measurement of the width to determine the cross-sectional area. The center width dimension should be recorded to the nearest 0.005 in. (0.127 mm), and the thickness measurement to the nearest 0.001 in. (0.025 mm).

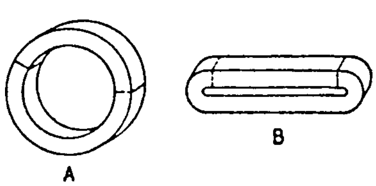
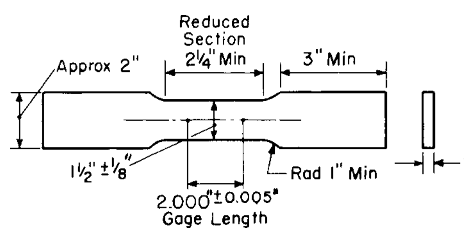


FIG. A2.4 Location of Transverse Tension Test Specimens in Ring Cut from Tubular Products.



NOTE 1—The dimension *t* is the thickness of the test specimen as provided for in the applicable material specifications.

NOTE 2—The reduced section shall be parallel within 0.010 in. and may have a gradual taper in width from the ends toward the center, with the ends not more than 0.010 in. wider than the center.

NOTE 3—The ends of the specimen shall be symmetrical with the center line of the reduced section within 0.10 in.

NOTE 4—Metric equivalent: 1 in. = 25.4 mm.

FIG. A2.5 Transverse Tension Test Specimen Machined from Ring Cut from Tubular Products

A2.2.4 *Round Test Specimens*:

A2.2.4.1 When provided for in the product specification, the round test specimen shown in Fig. 4 may be used.

A2.2.4.2 The diameter of the round test specimen is measured at the center of the specimen to the nearest 0.001 in. (0.025 mm).

A2.2.4.3 Small-size specimens proportional to standard, as shown in Fig. 4, may be used when it is necessary to test material from which the standard specimen cannot be prepared. Other sizes of small-size specimens may be used. In any such small-size specimen, it is important that the gauge length for measurement of elongation be four times the diameter of the specimen (see Note 4, Fig. 4). The elongation requirements for the round specimen 2-in. gauge length in the product specification shall apply to the small-size specimens.

A2.2.4.4 For transverse specimens, the section from which the specimen is taken shall not be flattened or otherwise deformed.

A2.2.4.5 Longitudinal test specimens are obtained from strips cut from the tubular product as shown in Fig. A2.2.

A2.3 Determination of Transverse Yield Strength, Hydraulic Ring-Expansion Method

A2.3.1 Hardness tests are made on the outside surface, inside surface, or wall cross-section depending upon product-specification limitation. Surface preparation may be necessary to obtain accurate hardness values.

A2.3.2 A testing machine and method for determining the transverse yield strength from an annular ring specimen, have been developed and described in A2.3.3-8.1.2.

A2.3.3 A diagrammatic vertical cross-sectional sketch of the testing machine is shown in Fig. A2.6.

A2.3.4 In determining the transverse yield strength on this machine, a short ring (commonly 3 in. (76 mm) in length) test specimen is used. After the large circular nut is removed from the machine, the wall thickness of the ring specimen is determined and the specimen is telescoped over the oil resistant rubber gasket. The nut is then replaced, but is not turned down tight against the specimen. A slight clearance is left between the nut and specimen for the purpose of permitting free radial movement of the specimen as it is being tested. Oil under pressure is then admitted to the interior of the rubber gasket through the pressure line under the control of a suitable valve. An accurately calibrated pressure gauge serves to measure oil pressure. Any air in the system is removed through the bleeder line. As the oil pressure is increased, the rubber gasket expands which in turn stresses the specimen circumferentially. As the pressure builds up, the lips of the rubber gasket act as a seal to prevent oil leakage. With continued increase in pressure, the ring specimen is subjected to a tension stress and elongates accordingly. The entire outside circumference of the ring specimen is considered as the gauge length and the strain is measured with a suitable extensometer which will be described later. When the desired total strain or extension under load is reached on the extensometer, the oil pressure in pounds per square inch is read and by employing Barlow's formula, the unit yield strength is calculated. The yield strength, thus determined, is a true result since the test specimen has not been cold worked by flattening and closely approximates the same condition as the tubular section from which it is cut. Further, the test closely simulates service conditions in pipe lines. One testing machine unit may be used for several different sizes of pipe by the use of suitable rubber gaskets and adapters.

NOTE A2.3—Barlow's formula may be stated two ways:

$$(1)\ P = 2St/D \quad (A2.2)$$

$$(2)\ S = PD/2t \quad (A2.3)$$

where:

P = internal hydrostatic pressure, psi,
S = unit circumferential stress in the wall of the tube produced by the internal hydrostatic pressure, psi,
t = thickness of the tube wall, in., and
D = outside diameter of the tube, in.

A2.3.5 A roller chain type extensometer which has been found satisfactory for measuring the elongation of the ring specimen is shown in Fig. A2.7 and Fig. A2.8. Fig. A2.7 shows the extensometer in position, but unclamped, on a ring specimen. A small pin, through which the strain is transmitted to and measured by the dial gauge, extends through the hollow threaded stud. When the extensometer is clamped, as shown in Fig. A2.8, the desired tension which is necessary to hold the instrument in place and to remove any slack, is exerted on the roller chain by the spring. Tension on the spring may be

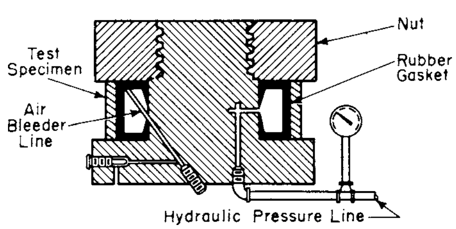


FIG. A2.6 Testing Machine for Determination of Transverse Yield Strength from Annular Ring Specimens

FIG. A2.7 Roller Chain Type Extensometer, Unclamped

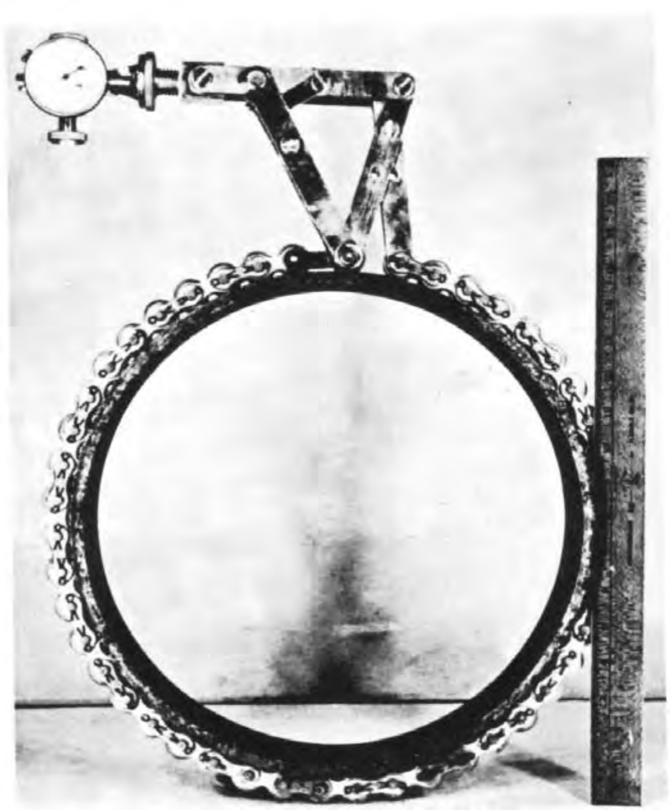


FIG. A2.8 Roller Chain Type Extensometer, Clamped

regulated as desired by the knurled thumb screw. By removing or adding rollers, the roller chain may be adapted for different sizes of tubular sections.

A2.4 Hardness Tests

A2.4.1 Hardness tests are made either on the outside or the inside surfaces on the end of the tube as appropriate.

A2.4.2 The standard 3000-kgf Brinell load may cause too much deformation in a thin-walled tubular specimen. In this case the 500-kgf load shall be applied, or inside stiffening by means of an internal anvil should be used. Brinell testing shall not be applicable to tubular products less than 2 in. (51 mm) in outside diameter, or less than 0.200 in. (5.1 mm) in wall thickness.

A2.4.3 The Rockwell hardness tests are normally made on the inside surface, a flat on the outside surface, or on the wall cross-section depending upon the product limitation. Rockwell hardness tests are not performed on tubes smaller than 5⁄16 in. (7.9 mm) in outside diameter, nor are they performed on the inside surface of tubes with less than ¼ in. (6.4 mm) inside diameter. Rockwell hardness tests are not performed on annealed tubes with walls less than 0.065 in. (1.65 mm) thick or cold worked or heat treated tubes with walls less than 0.049 in. (1.24 mm) thick. For tubes with wall thicknesses less than those permitting the regular Rockwell hardness test, the Superficial Rockwell test is sometimes substituted. Transverse Rockwell hardness readings can be made on tubes with a wall thickness of 0.187 in. (4.75 mm) or greater. The curvature and the wall thickness of the specimen impose limitations on the Rockwell hardness test. When a comparison is made between Rockwell determinations made on the outside surface and determinations made on the inside surface, adjustment of the readings will be required to compensate for the effect of curvature. The Rockwell B scale is used on all materials having an expected hardness range of B0 to B100. The Rockwell C scale is used on material having an expected hardness range of C20 to C68.

A2.4.4 Superficial Rockwell hardness tests are normally performed on the outside surface whenever possible and whenever excessive spring back is not encountered. Otherwise, the tests may be performed on the inside. Superficial Rockwell hardness tests shall not be performed on tubes with an inside diameter of less than ¼ in. (6.4 mm). The wall thickness limitations for the Superficial Rockwell hardness test are given in Table A2.1 and Table A2.2.

A2.4.5 When the outside diameter, inside diameter, or wall thickness precludes the obtaining of accurate hardness values, tubular products shall be specified to tensile properties and so tested.

A2.5 Manipulating Tests

A2.5.1 The following tests are made to prove ductility of certain tubular products:

A2.5.1.1 *Flattening Test*—The flattening test as commonly made on specimens cut from tubular products is conducted by subjecting rings from the tube or pipe to a prescribed degree of flattening between parallel plates (Fig. A2.4). The severity of the flattening test is measured by the distance between the parallel plates and is varied according to the dimensions of the tube or pipe. The flattening test specimen should not be less than 2½ in. (63.5 mm) in length and should be flattened cold to the extent required by the applicable material specifications.

A2.5.1.2 *Reverse Flattening Test*—The reverse flattening test is designed primarily for application to electric-welded tubing for the detection of lack of penetration or overlaps resulting from flash removal in the weld. The specimen consists of a length of tubing approximately 4 in. (102 mm) long which is split longitudinally 90° on each side of the weld. The sample is then opened and flattened with the weld at the point of maximum bend (Fig. A2.9).

TABLE A2.1 Wall Thickness Limitations of Superficial Hardness Test on Annealed or Ductile Materials for Steel Tubular Products[A]
("T" Scale (1⁄16-in. Ball))

Wall Thickness, in. (mm)	Load, kgf
Over 0.050 (1.27)	45
Over 0.035 (0.89)	30
0.020 and over (0.51)	15

[A] The heaviest load recommended for a given wall thickness is generally used.

TABLE A2.2 Wall Thickness Limitations of Superficial Hardness Test on Cold Worked or Heat Treated Material for Steel Tubular Products[A]
("N" Scale (Diamond Penetrator))

Wall Thickness, in. (mm)	Load, kgf
Over 0.035 (0.89)	45
Over 0.025 (0.51)	30
0.015 and over (0.38)	15

[A] The heaviest load recommended for a given wall thickness is generally used.

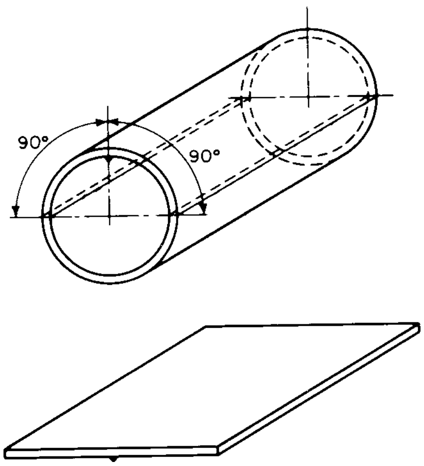


FIG. A2.9 Reverse Flattening Test

A2.5.1.3 *Crush Test*—The crush test, sometimes referred to as an upsetting test, is usually made on boiler and other pressure tubes, for evaluating ductility (Fig. A2.10). The specimen is a ring cut from the tube, usually about 2½ in. (63.5 mm) long. It is placed on end and crushed endwise by hammer or press to the distance prescribed by the applicable material specifications.

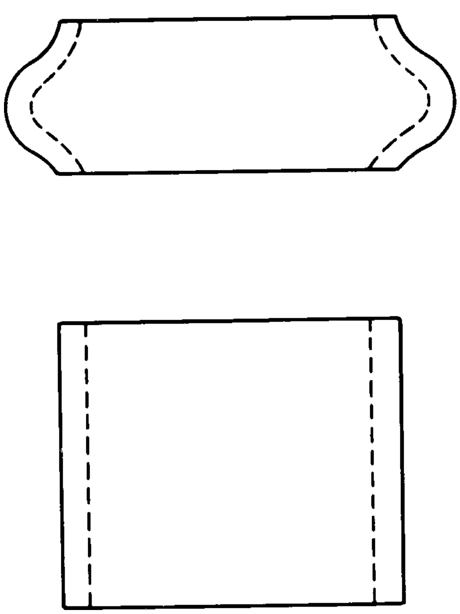


FIG. A2.10 Crush Test Specimen

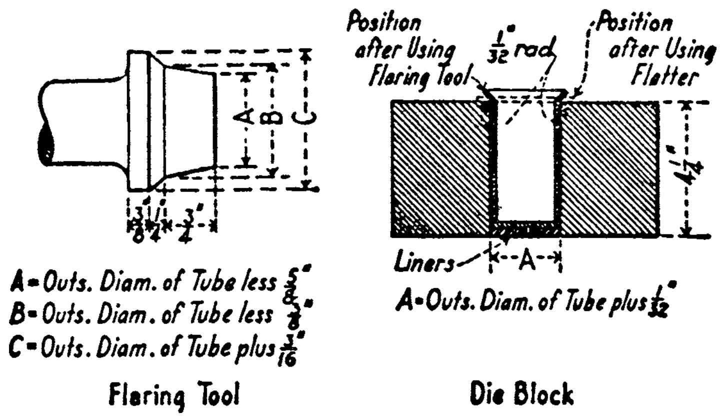
A2.5.1.4 *Flange Test*—The flange test is intended to determine the ductility of boiler tubes and their ability to withstand the operation of bending into a tube sheet. The test is made on a ring cut from a tube, usually not less than 4 in. (100 mm) long and consists of having a flange turned over at right angles to the body of the tube to the width required by the applicable material specifications. The flaring tool and die block shown in Fig. A2.11 are recommended for use in making this test.

A2.5.1.5 *Flaring Test*—For certain types of pressure tubes, an alternate to the flange test is made. This test consists of driving a tapered mandrel having a slope of 1 in 10 as shown in Fig. A2.12 (*a*) or a 60° included angle as shown in Fig. A2.12 (*b*) into a section cut from the tube, approximately 4 in. (100 mm) in length, and thus expanding the specimen until the inside diameter has been increased to the extent required by the applicable material specifications.

A2.5.1.6 *Bend Test*—For pipe used for coiling in sizes 2 in. and under a bend test is made to determine its ductility and the soundness of weld. In this test a sufficient length of full-size pipe is bent cold through 90° around a cylindrical mandrel having a diameter 12 times the nominal diameter of the pipe. For close coiling, the pipe is bent cold through 180° around a mandrel having a diameter 8 times the nominal diameter of the pipe.

A2.5.1.7 *Transverse Guided Bend Test of Welds*—This bend test is used to determine the ductility of fusion welds. The specimens used are approximately 1½ in. (38 mm) wide, at least 6 in. (152 mm) in length with the weld at the center, and are machined in accordance with Fig. A2.13 for face and root bend tests and in accordance with Fig. A2.14 for side bend tests. The dimensions of the plunger shall be as shown in Fig. A2.15 and the other dimensions of the bending jig shall be substantially as given in this same figure. A test shall consist of a face bend specimen and a root bend specimen or two side bend specimens. A face bend test requires bending with the inside surface of the pipe against the plunger; a root bend test requires bending with the outside surface of the pipe against the plunger; and a side bend test requires bending so that one of the side surfaces becomes the convex surface of the bend specimen.

(a) Failure of the bend test depends upon the appearance of cracks in the area of the bend, of the nature and extent described in the product specifications.



NOTE 1—Metric equivalent: 1 in. = 25.4 mm.

FIG. A2.11 Flaring Tool and Die Block for Flange Test

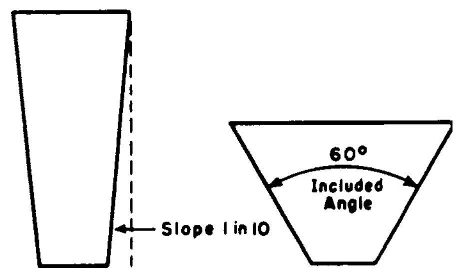
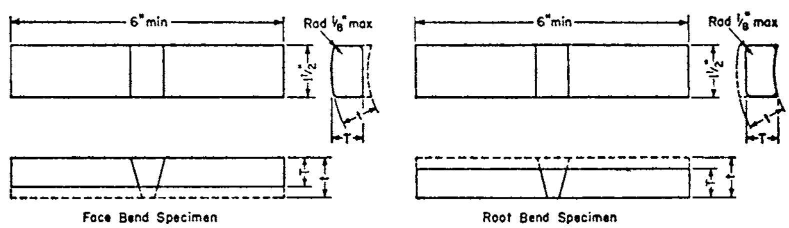


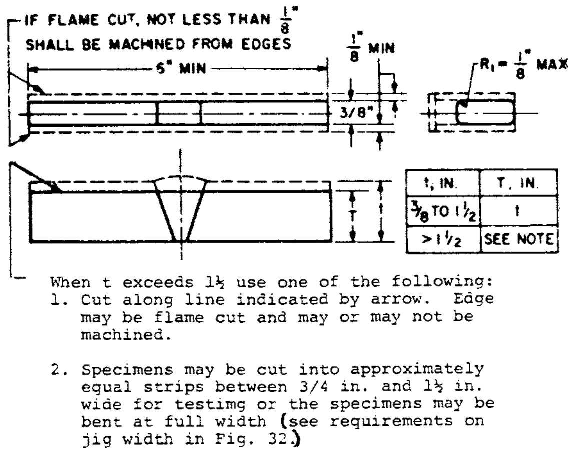
FIG. A2.12 Tapered Mandrels for Flaring Test



NOTE 1—Metric equivalent: 1 in. = 25.4 mm.

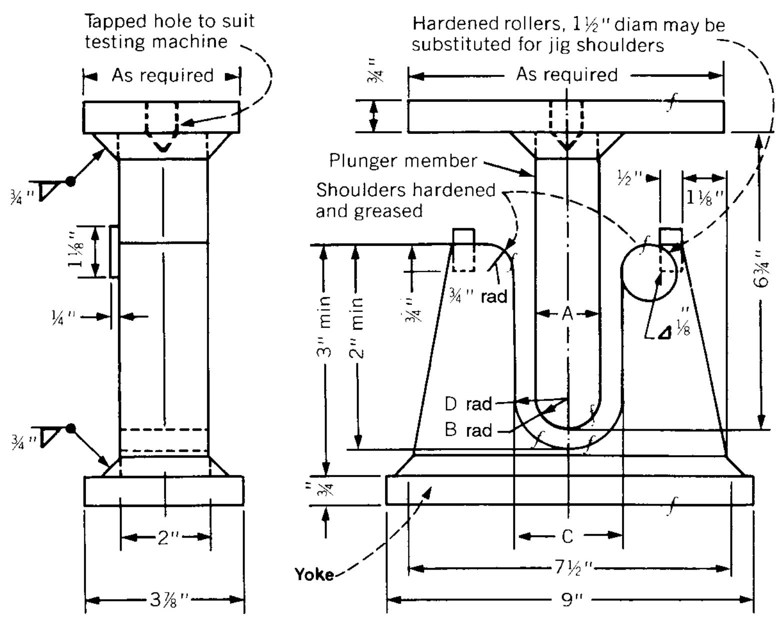
Pipe Wall Thickness (*t*), in.	Test Specimen Thickness, in.
Up to 3⁄8 , incl	*t*
Over 3⁄8	3⁄8

FIG. A2.13 Transverse Face- and Root-Bend Test Specimens



NOTE 1—Metric equivalent: 1 in. = 25.4 mm.

FIG. A2.14 Side-Bend Specimen for Ferrous Materials



NOTE 1—Metric equivalent: 1 in. = 25.4 mm.

Test Specimen Thickness, in.	A	B	C	D	
⅜	1½	¾	2⅜	1 3/16	
t	4*t*	2*t*	6*t* + ⅛	3*t* + 1/16	
					Material
⅜	2½	1¼	3⅜	1 11/16	Materials with a specified minimum tensile strength of 95 ksi or greater.
t	6⅔ *t*	3⅓ *t*	8⅔ *t* + ⅛	4½ *t* + 1/16	

FIG. A2.15 Guided-Bend Test Jig

A3. STEEL FASTENERS

A3.1 Scope

A3.1.1 This supplement covers definitions and methods of testing peculiar to steel fasteners which are not covered in the general section of Test Methods and Definitions A 370. Standard tests required by the individual product specifications are to be performed as outlined in the general section of these methods.

A3.1.2 These tests are set up to facilitate production control testing and acceptance testing with certain more precise tests to be used for arbitration in case of disagreement over test results.

A3.2 Tension Tests

A3.2.1 It is preferred that bolts be tested full size, and it is customary, when so testing bolts to specify a minimum ultimate load in pounds, rather than a minimum ultimate strength in pounds per square inch. Three times the bolt nominal diameter has been established as the minimum bolt length subject to the tests described in the remainder of this section. Sections A3.2.1.1-A3.2.1.3 apply when testing bolts full size. Section A3.2.1.4 shall apply where the individual product specifications permit the use of machined specimens.

A3.2.1.1 *Proof Load*— Due to particular uses of certain classes of bolts it is desirable to be able to stress them, while in use, to a specified value without obtaining any permanent set. To be certain of obtaining this quality the proof load is specified. The proof load test consists of stressing the bolt with a specified load which the bolt must withstand without permanent set. An alternate test which determines yield strength of a full size bolt is also allowed. Either of the following Methods, 1 or 2, may be used but Method 1 shall be the arbitration method in case of any dispute as to acceptance of the bolts.

A3.2.1.2 *Proof Load Testing Long Bolts*—When full size tests are required, proof load Method 1 is to be limited in application to bolts whose length does not exceed 8 in. (203 mm) or 8 times the nominal diameter, whichever is greater. For bolts longer than 8 in. or 8 times the nominal diameter, whichever is greater, proof load Method 2 shall be used.

(a) *Method 1, Length Measurement*—The overall length of a straight bolt shall be measured at its true center line with an instrument capable of measuring changes in length of 0.0001 in. (0.0025 mm) with an accuracy of 0.0001 in. in any 0.001-in. (0.025-mm) range. The preferred method of measuring the length shall be between conical centers machined on the center line of the bolt, with mating centers on the measuring anvils. The head or body of the bolt shall be marked so that it can be placed in the same position for all measurements. The bolt shall be assembled in the testing equipment as outlined in A3.2.1.4, and the proof load specified in the product specification shall be applied. Upon release of this load the length of the bolt shall be again measured and shall show no permanent elongation. A tolerance of ±0.0005 in. (0.0127 mm) shall be allowed between the measurement made before loading and that made after loading. Variables, such as straightness and thread alignment (plus measurement error), may result in apparent elongation of the fasteners when the proof load is initially applied. In such cases, the fastener may be retested using a 3 percent greater load, and may be considered satisfactory if the length after this loading is the same as before this loading (within the 0.0005-in. tolerance for measurement error).

A3.2.1.3 *Proof Load-Time of Loading*—The proof load is to be maintained for a period of 10 s before release of load, when using Method 1.

(*1*) *Method 2, Yield Strength*—The bolt shall be assembled in the testing equipment as outlined in A3.2.1.4. As the load is applied, the total elongation of the bolt or any part of the bolt which includes the exposed six threads shall be measured and recorded to produce a load-strain or a stress-strain diagram. The load or stress at an offset equal to 0.2 percent of the length of bolt occupied by 6 full threads shall be determined by the method described in 13.2.1 of these methods, A 370. This load or stress shall not be less than that prescribed in the product specification.

A3.2.1.4 *Axial Tension Testing of Full Size Bolts*—Bolts are to be tested in a holder with the load axially applied between the head and a nut or suitable fixture (Fig. A3.1), either of which shall have sufficient thread engagement to develop the full strength of the bolt. The nut or fixture shall be assembled on the bolt leaving six complete bolt threads unengaged between the grips, except for heavy hexagon structural bolts which shall have four complete threads unengaged between the grips. To meet the requirements of this test there shall be a tensile failure in the body or threaded section with no failure at the junction of the body, and head. If it is necessary to record or report the tensile strength of bolts as psi values the stress area shall be calculated from the mean of the mean root and pitch diameters of Class 3 external threads as follows:

$$A_s = 0.7854\,[D - (0.9743/n)]^2 \tag{A3.1}$$

where:
A_s = stress area, in.^{2},
D = nominal diameter, in., and
n = number of threads per inch.

A3.2.1.5 *Tension Testing of Full-Size Bolts with a Wedge*—The purpose of this test is to obtain the tensile strength and demonstrate the "head quality" and ductility of a bolt with a standard head by subjecting it to eccentric loading. The ultimate load on the bolt shall be determined as described in A3.2.1.4, except that a 10° wedge shall be placed under the same bolt previously tested for the proof load (see A3.2.1.1). The bolt head shall be so placed that no corner of the hexagon or square takes a bearing load, that is, a flat of the head shall be aligned with the direction of uniform thickness of the wedge (Fig. A3.2). The wedge shall have an included angle of 10°

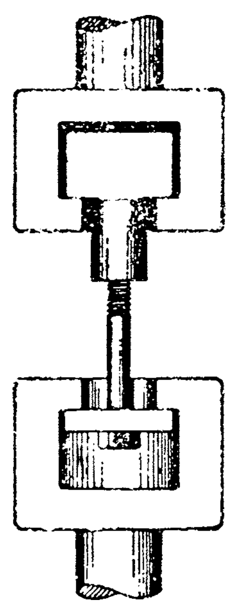
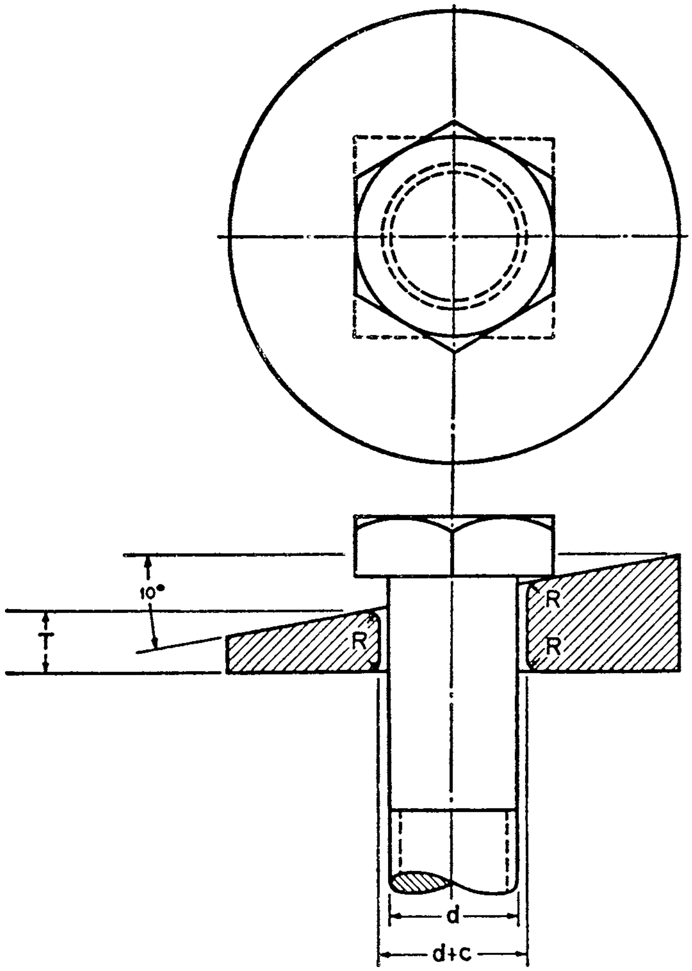


FIG. A3.1 Tension Testing Full-Size Bolt



c = Clearance of wedge hole
d = Diameter of bolt
R = Radius
T = Thickness of wedge at short side of hole equal to one-half diameter of bolt

FIG. A3.2 Wedge Test Detail

between its faces and shall have a thickness of one-half of the nominal bolt diameter at the short side of the hole. The hole in the wedge shall have the following clearance over the nominal size of the bolt, and its edges, top and bottom, shall be rounded to the following radius:

Nominal Bolt Size, in.	Clearance in Hole, in. (mm)	Radius on Corners of Hole, in. (mm)
¼ to ½	0.030 (0.76)	0.030 (0.76)
9⁄16 to ¾	0.050 (1.3)	0.060 (1.5)
⅞ to 1	0.063 (1.5)	0.060 (1.5)
1⅛ to 1¼	0.063 (1.5)	0.125 (3.2)
1⅜ to 1½	0.094 (2.4)	0.125 (3.2)

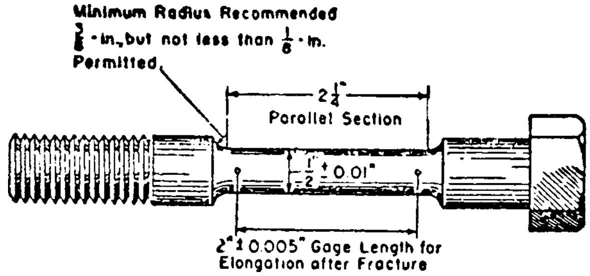
A3.2.1.6 *Wedge Testing of HT Bolts Threaded to Head*—For heat-treated bolts over 100 000 psi (690 MPa) minimum tensile strength and that are threaded 1 diameter and closer to the underside of the head, the wedge angle shall be 6° for sizes ¼ through ¾ in. (6.35 to 19.0 mm) and 4° for sizes over ¾ in.

A3.2.1.7 *Tension Testing of Bolts Machined to Round Test Specimens*:

(1) Bolts under 1½ in. (38 mm) in diameter which require machined tests shall preferably use a standard ½-in., (13-mm) round 2-in. (50-mm) gauge length test specimen (Fig. 4); however, bolts of small cross-section that will not permit the taking of this standard test specimen shall use one of the small-size-specimens-proportional-to-standard (Fig. 4) and the specimen shall have a reduced section as large as possible. In all cases, the longitudinal axis of the specimen shall be concentric with the axis of the bolt; the head and threaded section of the bolt may be left intact, as in Fig. A3.3 and Fig. A3.4, or shaped to fit the holders or grips of the testing machine so that the load is applied axially. The gauge length for measuring the elongation shall be four times the diameter of the specimen.

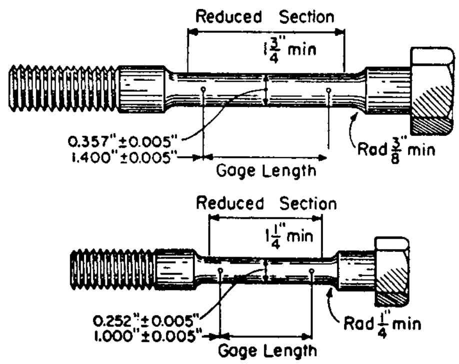
(2) For bolts 1½ in. and over in diameter, a standard ½-in. round 2-in. gauge length test specimen shall be turned from the bolt, having its axis midway between the center and outside surface of the body of the bolt as shown in Fig. A3.5.

(3) Machined specimens are to be tested in tension to determine the properties prescribed by the product specifications. The methods of testing and determination of properties shall be in accordance with Section 13 of these test methods.



NOTE 1—Metric equivalent: 1 in. = 25.4 mm.

FIG. A3.3 Tension Test Specimen for Bolt with Turned-Down Shank



NOTE 1—Metric equivalent: 1 in. = 25.4 mm.

FIG. A3.4 Examples of Small Size Specimens Proportional to Standard 2-in. Gauge Length Specimen

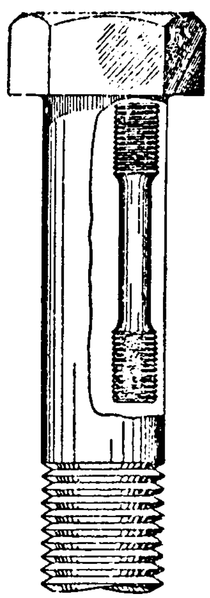
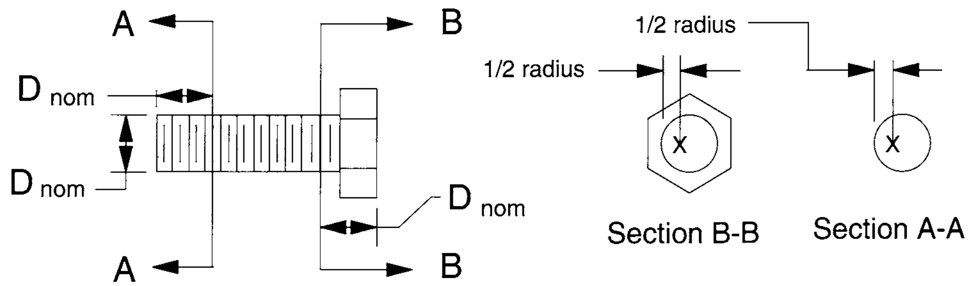


FIG. A3.5 Location of Standard Round 2-in. Gauge Length Tension Test Specimen When Turned from Large Size Bolt

A3.3 Hardness Tests for Externally Threaded Fasteners

A3.3.1 When specified, externally threaded fasteners shall be hardness tested. Fasteners with hexagonal or square heads shall be Brinell or Rockwell hardness tested on the side or top of the head. Externally threaded fasteners with other type of heads and those without heads shall be Brinell or Rockwell hardness tested on one end. Due to possible distortion from the Brinell load, care should be taken that this test meets the requirements of Section 16 of these test methods. Where the Brinell hardness test is impractical, the Rockwell hardness test shall be substituted. Rockwell hardness test procedures shall conform to Section 18 of these test methods.



X=Location of Hardness Impressions

FIG. A3.6 Hardness Test Locations for Bolts in a Dispute

A3.3.2 In cases where a dispute exists between buyer and seller as to whether externally threaded fasteners meet or exceed the hardness limit of the product specification, for purposes of arbitration, hardness may be taken on two transverse sections through a representative sample fastener selected at random. Hardness readings shall be taken at the locations shown in Fig. A3.6. All hardness values must conform with the hardness limit of the product specification in order for the fasteners represented by the sample to be considered in compliance. This provision for arbitration of a dispute shall not be used to accept clearly rejectable fasteners.

A3.4 Testing of Nuts

A3.4.1 *Proof Load*— A sample nut shall be assembled on a hardened threaded mandrel or on a bolt conforming to the particular specification. A load axial with the mandrel or bolt and equal to the specified proof load of the nut shall be applied. The nut shall resist this load without stripping or rupture. If the threads of the mandrel are damaged during the test the individual test shall be discarded. The mandrel shall be threaded to American National Standard Class 3 tolerance, except that the major diameter shall be the minimum major diameter with a tolerance of + 0.002 in. (0.051 mm).

A3.4.2 *Hardness Test*— Rockwell hardness of nuts shall be determined on the top or bottom face of the nut. Brinell hardness shall be determined on the side of the nuts. Either method may be used at the option of the manufacturer, taking into account the size and grade of the nuts under test. When the standard Brinell hardness test results in deforming the nut it will be necessary to use a minor load or substitute a Rockwell hardness test.

A4. ROUND WIRE PRODUCTS

A4.1 Scope

A4.1.1 This supplement covers the apparatus, specimens and methods of testing peculiar to steel wire products which are not covered in the general section of Test Methods A 370.

A4.2 Apparatus

A4.2.1 *Gripping Devices*—Grips of either the wedge or snubbing types as shown in Fig. A4.1 and Fig. A4.2 shall be used (Note A4.1). When using grips of either type, care shall be taken that the axis of the test specimen is located approximately at the center line of the head of the testing machine (Note A4.2). When using wedge grips the liners used behind the grips shall be of the proper thickness.

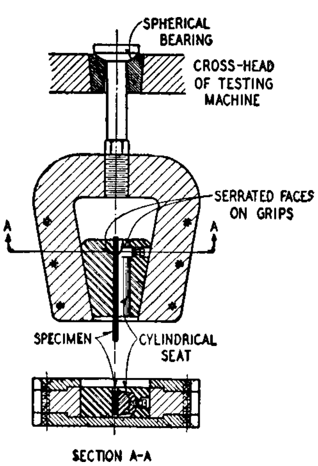


FIG. A4.1 Wedge-Type Gripping Device

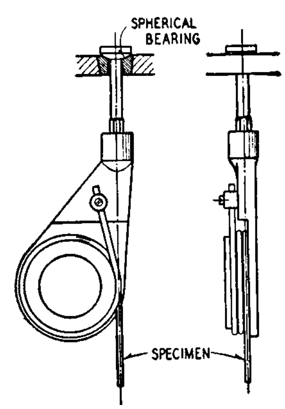


FIG. A4.2 Snubbing-Type Gripping Device

NOTE A4.1—Testing machines usually are equipped with wedge grips. These wedge grips, irrespective of the type of testing machine, may be referred to as the "usual type" of wedge grips. The use of fine (180 or 240) grit abrasive cloth in the "usual" wedge type grips, with the abrasive contacting the wire specimen, can be helpful in reducing specimen slipping and breakage at the grip edges at tensile loads up to about 1000 pounds. For tests of specimens of wire which are liable to be cut at the edges by the "usual type" of wedge grips, the snubbing type gripping device has proved satisfactory.

For testing round wire, the use of cylindrical seat in the wedge gripping device is optional.

NOTE A4.2—Any defect in a testing machine which may cause non-axial application of load should be corrected.

A4.2.2 *Pointed Micrometer*—A micrometer with a pointed spindle and anvil suitable for reading the dimensions of the wire specimen at the fractured ends to the nearest 0.001 in. (0.025 mm) after breaking the specimen in the testing machine shall be used.

A4.3 Test Specimens

A4.3.1 Test specimens having the full cross-sectional area of the wire they represent shall be used. The standard gauge length of the specimens shall be 10 in. (254 mm). However, if the determination of elongation values is not required, any convenient gauge length is permissible. The total length of the specimens shall be at least equal to the gauge length (10 in.) plus twice the length of wire required for the full use of the grip employed. For example, depending upon the type of testing machine and grips used, the minimum total length of specimen may vary from 14 to 24 in. (360 to 610 mm) for a 10-in. gauge length specimen.

A4.3.2 Any specimen breaking in the grips shall be discarded and a new specimen tested.

A4.4 Elongation

A4.4.1 In determining permanent elongation, the ends of the fractured specimen shall be carefully fitted together and the distance between the gauge marks measured to the nearest 0.01 in. (0.25 mm) with dividers and scale or other suitable device. The elongation is the increase in length of the gauge length, expressed as a percentage of the original gauge length. In recording elongation values, both the percentage increase and the original gauge length shall be given.

A4.4.2 In determining total elongation (elastic plus plastic extension) autographic or extensometer methods may be employed.

A4.4.3 If fracture takes place outside of the middle third of the gauge length, the elongation value obtained may not be representative of the material.

A4.5 Reduction of Area

A4.5.1 The ends of the fractured specimen shall be carefully fitted together and the dimensions of the smallest cross section measured to the nearest 0.001 in. (0.025 mm) with a pointed micrometer. The difference between the area thus found and the area of the original cross section, expressed as a percentage of the original area, is the reduction of area.

A4.5.2 The reduction of area test is not recommended in wire diameters less than 0.092 in. (2.34 mm) due to the difficulties of measuring the reduced cross sections.

A4.6 Rockwell Hardness Test

A4.6.1 On heat–treated wire of diameter 0.100 in. (2.54 mm) and larger, the specimen shall be flattened on two parallel sides by grinding before testing. The hardness test is not recommended for any diameter of hard drawn wire or heat-treated wire less than 0.100 in. (2.54 mm) in diameter. For round wire, the tensile strength test is greatly preferred over the hardness test.

A4.7 Wrap Test

A4.7.1 This test is used as a means for testing the ductility of certain kinds of wire.

A4.7.2 The test consists of coiling the wire in a closely spaced helix tightly against a mandrel of a specified diameter for a required number of turns. (Unless other specified, the required number of turns shall be five.) The wrapping may be done by hand or a power device. The wrapping rate may not exceed 15 turns per min. The mandrel diameter shall be specified in the relevant wire product specification.

A4.7.3 The wire tested shall be considered to have failed if the wire fractures or if any longitudinal or transverse cracks develop which can be seen by the unaided eye after the first complete turn. Wire which fails in the first turn shall be retested, as such fractures may be caused by bending the wire to a radius less than specified when the test starts.

A4.8 Coiling Test

A4.8.1 This test is used to determine if imperfections are present to the extent that they may cause cracking or splitting during spring coiling and spring extension. A coil of specified length is closed wound on an arbor of a specified diameter. The closed coil is then stretched to a specified permanent increase in length and examined for uniformity of pitch with no splits or fractures. The required arbor diameter, closed coil length, and permanent coil extended length increase may vary with wire diameter, properties, and type.

A5. NOTES ON SIGNIFICANCE OF NOTCHED-BAR IMPACT TESTING

A5.1 Notch Behavior

A5.1.1 The Charpy and Izod type tests bring out notch behavior (brittleness versus ductility) by applying a single overload of stress. The energy values determined are quantitative comparisons on a selected specimen but cannot be converted into energy values that would serve for engineering design calculations. The notch behavior indicated in an individual test applies only to the specimen size, notch geometry, and testing conditions involved and cannot be generalized to other sizes of specimens and conditions.

A5.1.2 The notch behavior of the face-centered cubic metals and alloys, a large group of nonferrous materials and the austenitic steels can be judged from their common tensile properties. If they are brittle in tension they will be brittle when notched, while if they are ductile in tension, they will be ductile when notched, except for unusually sharp or deep notches (much more severe than the standard Charpy or Izod specimens). Even low temperatures do not alter this characteristic of these materials. In contrast, the behavior of the ferritic steels under notch conditions cannot be predicted from their properties as revealed by the tension test. For the study of these materials the Charpy and Izod type tests are accordingly very useful. Some metals that display normal ductility in the tension test may nevertheless break in brittle fashion when tested or when used in the notched condition. Notched conditions include restraints to deformation in directions perpendicular to the major stress, or multiaxial stresses, and stress concentrations. It is in this field that the Charpy and Izod tests prove useful for determining the susceptibility of a steel to notch-brittle behavior though they cannot be directly used to appraise the serviceability of a structure.

A5.1.3 The testing machine itself must be sufficiently rigid or tests on high-strength low-energy materials will result in excessive elastic energy losses either upward through the pendulum shaft or downward through the base of the machine. If the anvil supports, the pendulum striking edge, or the machine foundation bolts are not securely fastened, tests on ductile materials in the range of 80 ft·lbf (108 J) may actually indicate values in excess of 90 to 100 ft·lbf (122 to 136 J).

A5.2 Notch Effect

A5.2.1 The notch results in a combination of multiaxial stresses associated with restraints to deformation in directions perpendicular to the major stress, and a stress concentration at the base of the notch. A severely notched condition is generally not desirable, and it becomes of real concern in those cases in which it initiates a sudden and complete failure of the brittle type. Some metals can be deformed in a ductile manner even down to the low temperatures of liquid air, while others may crack. This difference in behavior can be best understood by considering the cohesive strength of a material (or the property that holds it together) and its relation to the yield point. In cases of brittle fracture, the cohesive strength is exceeded before significant plastic deformation occurs and the fracture appears crystalline. In cases of the ductile or shear type of failure, considerable deformation precedes the final fracture and the broken surface appears fibrous instead of crystalline. In intermediate cases the fracture comes after a moderate amount of deformation and is part crystalline and part fibrous in appearance.

A5.2.2 When a notched bar is loaded, there is a normal stress across the base of the notch which tends to initiate fracture. The property that keeps it from cleaving, or holds it together, is the "cohesive strength." The bar fractures when the normal stress exceeds the cohesive strength. When this occurs without the bar deforming it is the condition for brittle fracture.

A5.2.3 In testing, though not in service because of side effects, it happens more commonly that plastic deformation precedes fracture. In addition to the normal stress, the applied load also sets up shear stresses which are about 45° to the normal stress. The elastic behavior terminates as soon as the shear stress exceeds the shear strength of the material and deformation or plastic yielding sets in. This is the condition for ductile failure.

A5.2.4 This behavior, whether brittle or ductile, depends on whether the normal stress exceeds the cohesive strength before the shear stress exceeds the shear strength. Several important facts of notch behavior follow from this. If the notch is made sharper or more drastic, the normal stress at the root of the notch will be increased in relation to the shear stress and the bar will be more prone to brittle fracture (see Table A5.1). Also, as the speed of deformation increases, the shear strength increases and the likelihood of brittle fracture increases. On the other hand, by raising the temperature, leaving the notch and the speed of deformation the same, the shear strength is lowered and ductile behavior is promoted, leading to shear failure.

A5.2.5 Variations in notch dimensions will seriously affect the results of the tests. Tests on E 4340 steel specimens[6] have shown the effect of dimensional variations on Charpy results (see Table A5.1).

A5.3 Size Effect

A5.3.1 Increasing either the width or the depth of the specimen tends to increase the volume of metal subject to distortion, and by this factor tends to increase the energy absorption when breaking the specimen. However, any increase in size, particularly in width, also tends to increase the degree of restraint and by tending to induce brittle fracture, may decrease the amount of energy absorbed. Where a standard-size specimen is on the verge of brittle fracture, this is particularly true, and a double-width specimen may actually require less energy for rupture than one of standard width.

A5.3.2 In studies of such effects where the size of the material precludes the use of the standard specimen, as for example when the material is ¼-in. plate, subsize specimens

[6] Fahey, N. H., "Effects of Variables in Charpy Impact Testing," *Materials Research & Standards*, Vol 1, No. 11, November, 1961, p. 872.

TABLE A5.1 Effect of Varying Notch Dimensions on Standard Specimens

	High-Energy Specimens, ft·lbf (J)	High-Energy Specimens, ft·lbf (J)	Low-Energy Specimens, ft·lbf (J)
Specimen with standard dimensions	76.0 ± 3.8 (103.0 ± 5.2)	44.5 ± 2.2 (60.3 ± 3.0)	12.5 ± 1.0 (16.9 ± 1.4)
Depth of notch, 0.084 in. (2.13 mm)^A	72.2 (97.9)	41.3 (56.0)	11.4 (15.5)
Depth of notch, 0.0805 in. (2.04 mm)^A	75.1 (101.8)	42.2 (57.2)	12.4 (16.8)
Depth of notch, 0.0775 in. (1.77 mm)^A	76.8 (104.1)	45.3 (61.4)	12.7 (17.2)
Depth of notch, 0.074 in. (1.57 mm)^A	79.6 (107.9)	46.0 (62.4)	12.8 (17.3)
Radius at base of notch, 0.005 in. (0.127 mm)^B	72.3 (98.0)	41.7 (56.5)	10.8 (14.6)
Radius at base of notch, 0.015 in. (0.381 mm)^B	80.0 (108.5)	47.4 (64.3)	15.8 (21.4)

^{A} Standard 0.079 ± 0.002 in. (2.00 ± 0.05 mm).
^{B} Standard 0.010 ± 0.001 in. (0.25 ± 0.025 mm).

are necessarily used. Such specimens (see Fig. 6 of Test Methods E 23) are based on the Type A specimen of Fig. 4 of Test Methods E 23.

A5.3.3 General correlation between the energy values obtained with specimens of different size or shape is not feasible, but limited correlations may be established for specification purposes on the basis of special studies of particular materials and particular specimens. On the other hand, in a study of the relative effect of process variations, evaluation by use of some arbitrarily selected specimen with some chosen notch will in most instances place the methods in their proper order.

A5.4 Effects of Testing Conditions

A5.4.1 The testing conditions also affect the notch behavior. So pronounced is the effect of temperature on the behavior of steel when notched that comparisons are frequently made by examining specimen fractures and by plotting energy value and fracture appearance versus temperature from tests of notched bars at a series of temperatures. When the test temperature has been carried low enough to start cleavage fracture, there may be an extremely sharp drop in impact value or there may be a relatively gradual falling off toward the lower temperatures. This drop in energy value starts when a specimen begins to exhibit some crystalline appearance in the fracture. The transition temperature at which this embrittling effect takes place varies considerably with the size of the part or test specimen and with the notch geometry.

A5.4.2 Some of the many definitions of transition temperature currently being used are: (*1*) the lowest temperature at which the specimen exhibits 100 % fibrous fracture, (*2*) the temperature where the fracture shows a 50 % crystalline and a 50 % fibrous appearance, (*3*) the temperature corresponding to the energy value 50 % of the difference between values obtained at 100 % and 0 % fibrous fracture, and (*4*) the temperature corresponding to a specific energy value.

A5.4.3 A problem peculiar to Charpy-type tests occurs when high-strength, low-energy specimens are tested at low temperatures. These specimens may not leave the machine in the direction of the pendulum swing but rather in a sidewise direction. To ensure that the broken halves of the specimens do not rebound off some component of the machine and contact the pendulum before it completes its swing, modifications may be necessary in older model machines. These modifications differ with machine design. Nevertheless the basic problem is the same in that provisions must be made to prevent rebounding of the fractured specimens into any part of the swinging pendulum. Where design permits, the broken specimens may be deflected out of the sides of the machine and yet in other designs it may be necessary to contain the broken specimens within a certain area until the pendulum passes through the anvils. Some low-energy high-strength steel specimens leave impact machines at speeds in excess of 50 ft (15.3 m)/s although they were struck by a pendulum traveling at speeds approximately 17 ft (5.2 m)/s. If the force exerted on the pendulum by the broken specimens is sufficient, the pendulum will slow down and erroneously high energy values will be recorded. This problem accounts for many of the inconsistencies in Charpy results reported by various investigators within the 10 to 25-ft·lbf (14 to 34 J) range. The Apparatus Section (the paragraph regarding Specimen Clearance) of Test Methods E 23 discusses the two basic machine designs and a modification found to be satisfactory in minimizing jamming.

A5.5 Velocity of Straining

A5.5.1 Velocity of straining is likewise a variable that affects the notch behavior of steel. The impact test shows somewhat higher energy absorption values than the static tests above the transition temperature and yet, in some instances, the reverse is true below the transition temperature.

A5.6 Correlation with Service

A5.6.1 While Charpy or Izod tests may not directly predict the ductile or brittle behavior of steel as commonly used in large masses or as components of large structures, these tests can be used as acceptance tests of identity for different lots of the same steel or in choosing between different steels, when correlation with reliable service behavior has been established. It may be necessary to make the tests at properly chosen temperatures other than room temperature. In this, the service temperature or the transition temperature of full-scale specimens does not give the desired transition temperatures for Charpy or Izod tests since the size and notch geometry may be so different. Chemical analysis, tension, and hardness tests may not indicate the influence of some of the important processing factors that affect susceptibility to brittle fracture nor do they comprehend the effect of low temperatures in inducing brittle behavior.

A6. PROCEDURE FOR CONVERTING PERCENTAGE ELONGATION OF A STANDARD ROUND TENSION TEST SPECIMEN TO EQUIVALENT PERCENTAGE ELONGATION OF A STANDARD FLAT SPECIMEN

A6.1 Scope

A6.1.1 This method specifies a procedure for converting percentage elongation after fracture obtained in a standard 0.500-in. (12.7-mm) diameter by 2-in. (51-mm) gauge length test specimen to standard flat test specimens ½ in. by 2 in. and 1½ in. by 8 in. (38.1 by 203 mm).

A6.2 Basic Equation

A6.2.1 The conversion data in this method are based on an equation by Bertella,[7] and used by Oliver[8] and others. The relationship between elongations in the standard 0.500-in. diameter by 2.0-in. test specimen and other standard specimens can be calculated as follows:

$$e = e_o\, [4.47\, (\sqrt{A})/L]^a \quad \text{(A6.1)}$$

where:

e_o = percentage elongation after fracture on a standard test specimen having a 2-in. gauge length and 0.500-in. diameter,

e = percentage elongation after fracture on a standard test specimen having a gauge length L and a cross-sectional area A, and

a = constant characteristic of the test material.

A6.3 Application

A6.3.1 In applying the above equation the constant *a* is characteristic of the test material. The value *a* = 0.4 has been found to give satisfactory conversions for carbon, carbon-manganese, molybdenum, and chromium-molybdenum steels within the tensile strength range of 40 000 to 85 000 psi (275 to 585 MPa) and in the hot-rolled, in the hot-rolled and normalized, or in the annealed condition, with or without tempering. Note that the cold reduced and quenched and tempered states are excluded. For annealed austenitic stainless steels, the value *a* = 0.127 has been found to give satisfactory conversions.

A6.3.2 Table A6.1 has been calculated taking *a* = 0.4, with the standard 0.500-in. (12.7-mm) diameter by 2-in. (51-mm) gauge length test specimen as the reference specimen. In the case of the subsize specimens 0.350 in. (8.89 mm) in diameter by 1.4-in. (35.6-mm) gauge length, and 0.250-in. (6.35- mm) diameter by 1.0-in. (25.4-mm) gauge length the factor in the equation is 4.51 instead of 4.47. The small error introduced by using Table A6.1 for the subsized specimens may be neglected. Table A6.2 for annealed austenitic steels has been calculated taking *a* = 0.127, with the standard 0.500-in. diameter by 2-in. gauge length test specimen as the reference specimen.

A6.3.3 Elongation given for a standard 0.500-in. diameter by 2-in. gauge length specimen may be converted to elongation for ½ in. by 2 in. or 1½ in. by 8-in. (38.1 by 203-mm) flat specimens by multiplying by the indicated factor in Table A6.1 and Table A6.2.

A6.3.4 These elongation conversions shall not be used where the width to thickness ratio of the test piece exceeds 20, as in sheet specimens under 0.025 in. (0.635 mm) in thickness.

TABLE A6.1 Carbon and Alloy Steels—Material Constant *a* = 0.4. Multiplication Factors for Converting Percent Elongation from ½-in. Diameter by 2-in. Gauge Length Standard Tension Test Specimen to Standard ½ by 2-in. and 1½ by 8-in. Flat Specimens

Thickness, in.	½ by 2-in. Specimen	1½ by 8-in. Specimen	Thickness in.	1½ by 8-in. Specimen
0.025	0.574	. . .	0.800	0.822
0.030	0.596	. . .	0.850	0.832
0.035	0.614	. . .	0.900	0.841
0.040	0.631	. . .	0.950	0.850
0.045	0.646	. . .	1.000	0.859
0.050	0.660	. . .	1.125	0.880
0.055	0.672	. . .	1.250	0.898
0.060	0.684	. . .	1.375	0.916
0.065	0.695	. . .	1.500	0.932
0.070	0.706	. . .	1.625	0.947
0.075	0.715	. . .	1.750	0.961
0.080	0.725	. . .	1.875	0.974
0.085	0.733	. . .	2.000	0.987
0.090	0.742	0.531	2.125	0.999
0.100	0.758	0.542	2.250	1.010
0.110	0.772	0.553	2.375	1.021
0.120	0.786	0.562	2.500	1.032
0.130	0.799	0.571	2.625	1.042
0.140	0.810	0.580	2.750	1.052
0.150	0.821	0.588	2.875	1.061
0.160	0.832	0.596	3.000	1.070
0.170	0.843	0.603	3.125	1.079
0.180	0.852	0.610	3.250	1.088
0.190	0.862	0.616	3.375	1.096
0.200	0.870	0.623	3.500	1.104
0.225	0.891	0.638	3.625	1.112
0.250	0.910	0.651	3.750	1.119
0.275	0.928	0.664	3.875	1.127
0.300	0.944	0.675	4.000	1.134
0.325	0.959	0.686	. . .	. . .
0.350	0.973	0.696	. . .	. . .
0.375	0.987	0.706	. . .	. . .
0.400	1.000	0.715	. . .	. . .
0.425	1.012	0.724	. . .	. . .
0.450	1.024	0.732	. . .	. . .
0.475	1.035	0.740	. . .	. . .
0.500	1.045	0.748	. . .	. . .
0.525	1.056	0.755	. . .	. . .
0.550	1.066	0.762	. . .	. . .
0.575	1.075	0.770	. . .	. . .
0.600	1.084	0.776	. . .	. . .
0.625	1.093	0.782	. . .	. . .
0.650	1.101	0.788	. . .	. . .
0.675	1.110	. . .	. . .	. . .
0.700	1.118	0.800	. . .	. . .
0.725	1.126	. . .	. . .	. . .
0.750	1.134	0.811	. . .	. . .

A6.3.5 While the conversions are considered to be reliable within the stated limitations and may generally be used in specification writing where it is desirable to show equivalent elongation requirements for the several standard ASTM tension specimens covered in Test Methods A 370, consideration must be given to the metallurgical effects dependent on the thickness of the material as processed.

[7] Bertella, C. A., *Giornale del Genio Civile*, Vol 60, 1922, p. 343.

[8] Oliver, D. A., *Proceedings of the Institution of Mechanical Engineers*, 1928, p. 827.

TABLE A6.2 Annealed Austenitic Stainless Steels—Material Constant *a* = 0.127. Multiplication Factors for Converting Percent Elongation from ½-in. Diameter by 2-in. Gauge Length Standard Tension Test Specimen to Standard ½ by 2-in. and 1½ by 8-in. Flat Specimens

Thickness, in.	½ by 2-in. Specimen	1½ by 8-in. Specimen	Thickness, in.	1½ by 8-in. Specimen
0.025	0.839	. . .	0.800	0.940
0.030	0.848	. . .	0.850	0.943
0.035	0.857	. . .	0.900	0.947
0.040	0.864	. . .	0.950	0.950
0.045	0.870	. . .	1.000	0.953
0.050	0.876	. . .	1.125	0.960
0.055	0.882	. . .	1.250	0.966
0.060	0.886	. . .	1.375	0.972
0.065	0.891	. . .	1.500	0.978
0.070	0.895	. . .	1.625	0.983
0.075	0.899	. . .	1.750	0.987
0.080	0.903	. . .	1.875	0.992
0.085	0.906	. . .	2.000	0.996
0.090	0.909	0.818	2.125	1.000
0.095	0.913	0.821	2.250	1.003
0.100	0.916	0.823	2.375	1.007
0.110	0.921	0.828	2.500	1.010
0.120	0.926	0.833	2.625	1.013
0.130	0.931	0.837	2.750	1.016
0.140	0.935	0.841	2.875	1.019
0.150	0.940	0.845	3.000	1.022
0.160	0.943	0.848	3.125	1.024
0.170	0.947	0.852	3.250	1.027
0.180	0.950	0.855	3.375	1.029
0.190	0.954	0.858	3.500	1.032
0.200	0.957	0.860	3.625	1.034
0.225	0.964	0.867	3.750	1.036
0.250	0.970	0.873	3.875	1.038
0.275	0.976	0.878	4.000	1.041
0.300	0.982	0.883	. . .	. . .
0.325	0.987	0.887	. . .	. . .
0.350	0.991	0.892	. . .	. . .
0.375	0.996	0.895	. . .	. . .
0.400	1.000	0.899	. . .	. . .
0.425	1.004	0.903	. . .	. . .
0.450	1.007	0.906	. . .	. . .
0.475	1.011	0.909	. . .	. . .
0.500	1.014	0.912	. . .	. . .
0.525	1.017	0.915	. . .	. . .
0.550	1.020	0.917	. . .	. . .
0.575	1.023	0.920	. . .	. . .
0.600	1.026	0.922	. . .	. . .
0.625	1.029	0.925	. . .	. . .
0.650	1.031	0.927	. . .	. . .
0.675	1.034	. . .	. . .	. . .
0.700	1.036	0.932	. . .	. . .
0.725	1.038	. . .	. . .	. . .
0.750	1.041	0.936	. . .	. . .

A7. METHOD OF TESTING MULTI-WIRE STRAND FOR PRESTRESSED CONCRETE

A7.1 Scope

A7.1.1 This method provides procedures for the tension testing of multi-wire strand for prestressed concrete. This method is intended for use in evaluating the strand properties prescribed in specifications for" prestressing steel strands."

A7.2 General Precautions

A7.2.1 Premature failure of the test specimens may result if there is any appreciable notching, cutting, or bending of the specimen by the gripping devices of the testing machine.

A7.2.2 Errors in testing may result if the seven wires constituting the strand are not loaded uniformly.

A7.2.3 The mechanical properties of the strand may be materially affected by excessive heating during specimen preparation.

A7.2.4 These difficulties may be minimized by following the suggested methods of gripping described in A7.4.

A7.3 Gripping Devices

A7.3.1 The true mechanical properties of the strand are determined by a test in which fracture of the specimen occurs in the free span between the jaws of the testing machine. Therefore, it is desirable to establish a test procedure with suitable apparatus which will consistently produce such results. Due to inherent physical characteristics of individual machines, it is not practical to recommend a universal gripping procedure that is suitable for all testing machines. Therefore, it is necessary to determine which of the methods of gripping described in A7.3.2 to A7.3.8 is most suitable for the testing equipment available.

A7.3.2 *Standard V-Grips with Serrated Teeth (Note A7.1)*.

A7.3.3 *Standard V-Grips with Serrated Teeth (Note A7.1), Using Cushioning Material*—In this method, some material is placed between the grips and the specimen to minimize the notching effect of the teeth. Among the materials which have been used are lead foil, aluminum foil, carborundum cloth, bra shims, etc. The type and thickness of material required is dependent on the shape, condition, and coarseness of the teeth.

A7.3.4 *Standard V-Grips with Serrated Teeth (Note A7.1), Using Special Preparation of the Gripped Portions of the Specimen*—One of the methods used is tinning, in which the gripped portions are cleaned, fluxed, and coated by multiple dips in molten tin alloy held just above the melting point. Another method of preparation is encasing the gripped portions in metal tubing or flexible conduit, using epoxy resin as the bonding agent. The encased portion should be approximately twice the length of lay of the strand.

A7.3.5 *Special Grips with Smooth, Semi-Cylindrical Grooves (Note A7.2)*—The grooves and the gripped portions of the specimen are coated with an abrasive slurry which holds the specimen in the smooth grooves, preventing slippage. The slurry consists of abrasive such as Grade 3-F aluminum oxide and a carrier such as water or glycerin.

A7.3.6 *Standard Sockets of the Type Used for Wire Rope*—The gripped portions of the specimen are anchored in the sockets with zinc. The special procedures for socketing usually employed in the wire rope industry must be followed.

A7.3.7 *Dead-End Eye Splices*—These devices are available in sizes designed to fit each size of strand to be tested.

A7.3.8 *Chucking Devices*—Use of chucking devices of the type generally employed for applying tension to strands in casting beds is not recommended for testing purposes.

NOTE A7.1—The number of teeth should be approximately 15 to 30 per in., and the minimum effective gripping length should be approximately 4 in. (102 mm).

NOTE A7.2—The radius of curvature of the grooves is approximately the same as the radius of the strand being tested, and is located 1⁄32 in. (0.79 mm) above the flat face of the grip. This prevents the two grips from closing tightly when the specimen is in place.

A7.4 Specimen Preparation

A7.4.1 If the molten-metal temperatures employed during hot-dip tinning or socketing with metallic material are too high, over approximately 700°F (370°C), the specimen may be heat affected with a subsequent loss of strength and ductility. Careful temperature controls should be maintained if such methods of specimen preparation are used.

A7.5 Procedure

A7.5.1 *Yield Strength*— For determining the yield strength use a Class B-1 extensometer (Note A7.3) as described in Practice E 83. Apply an initial load of 10 % of the expected minimum breaking strength to the specimen, then attach the extensometer and adjust it to a reading of 0.001 in./in. of gauge length. Then increase the load until the extensometer indicates an extension of 1 %. Record the load for this extension as the yield strength. The extensometer may be removed from the specimen after the yield strength has been determined.

A7.5.2 *Elongation*— For determining the elongation use a Class D extensometer (Note A7.3), as described in Practice E 83, having a gauge length of not less than 24 in. (610 mm) (Note A7.4). Apply an initial load of 10 % of the required minimum breaking strength to the specimen, then attach the extensometer (Note A7.3) and adjust it to a zero reading. The extensometer may be removed from the specimen prior to rupture after the specified minimum elongation has been exceeded. It is not necessary to determine the final elongation value.

A7.5.3 *Breaking Strength*—Determine the maximum load at which one or more wires of the strand are fractured. Record this load as the breaking strength of the strand.

NOTE A7.3—The yield-strength extensometer and the elongation extensometer may be the same instrument or two separate instruments. Two separate instruments are advisable since the more sensitive yield-strength extensometer, which could be damaged when the strand fractures, may be removed following the determination of yield strength. The elongation extensometer may be constructed with less sensitive parts or be constructed in such a way that little damage would result if fracture occurs while the extensometer is attached to the specimen.

NOTE A7.4—Specimens that break outside the extensometer or in the jaws and yet meet the minimum specified values are considered as meeting the mechanical property requirements of the product specification, regardless of what procedure of gripping has been used. Specimens that break outside of the extensometer or in the jaws and do not meet the minimum specified values are subject to retest. Specimens that break between the jaws and the extensometer and do not meet the minimum specified values are subject to retest as provided in the applicable specification.

A8. ROUNDING OF TEST DATA

A8.1 Rounding

A8.1.1 An observed value or a calculated value shall be rounded off in accordance with the applicable product specification. In the absence of a specified procedure, the rounding-off method of Practice E 29 shall be used.

A8.1.1.1 Values shall be rounded up or rounded down as determined by the rules of Practice E 29.

A8.1.1.2 In the special case of rounding the number "5" when no additional numbers other than "0" follow the "5," rounding shall be done in the direction of the specification limits if following Practice E 29 would cause rejection of material.

A8.1.2 Recommended levels for rounding reported values of test data are given in Table A8.1. These values are designed to provide uniformity in reporting and data storage, and should be used in all cases except where they conflict with specific requirements of a product specification.

NOTE A8.1—To minimize cumulative errors, whenever possible, values should be carried to at least one figure beyond that of the final (rounded) value during intervening calculations (such as calculation of stress from load and area measurements) with rounding occurring as the final operation. The precision may be less than that implied by the number of significant figures.

TABLE A8.1 Recommended Values for Rounding Test Data

Test Quantity	Test Data Range	Rounded Value[A]
Yield Point, Yield Strength, Tensile Strength	up to 50 000 psi, excl (up to 50 ksi) 50 000 to 100 000 psi, excl (50 to 100 ksi) 100 000 psi and above (100 ksi and above)	100 psi (0.1 ksi) 500 psi (0.5 ksi) 1000 psi (1.0 ksi)
	up to 500 MPa, excl 500 to 1000 MPa, excl 1000 MPa and above	1 MPa 5 MPa 10 MPa
Elongation	0 to 10 %, excl 10 % and above	0.5 % 1 %
Reduction of Area	0 to 10 %, excl 10 % and above	0.5 % 1 %
Impact Energy	0 to 240 ft·lbf (or 0 to 325 J)	1 ft·lbf (or 1 J)[B]
Brinell Hardness	all values	tabular value[C]
Rockwell Hardness	all scales	1 Rockwell Number

[A] Round test data to the nearest integral multiple of the values in this column. If the data value is exactly midway between two rounded values, round in accordance with A8.1.1.2.

[B] These units are not equivalent but the rounding occurs in the same numerical ranges for each. (1 ft·lbf = 1.356 J.)

[C] Round the mean diameter of the Brinell impression to the nearest 0.05 mm and report the corresponding Brinell hardness number read from the table without further rounding.

A9. METHODS FOR TESTING STEEL REINFORCING BARS

A9.1 Scope

A9.1.1 This annex covers additional details specific to testing steel reinforcing bars for use in concrete reinforcement.

A9.2 Test Specimens

A9.2.1 All test specimens shall be the full section of the bar as rolled.

A9.3 Tension Testing

A9.3.1 *Test Specimen*— Specimens for tension tests shall be long enough to provide for an 8-in. (200-mm) gauge length, a distance of at least two bar diameters between each gauge mark and the grips, plus sufficient additional length to fill the grips completely leaving some excess length protruding beyond each grip.

A9.3.2 *Gripping Device*— The grips shall be shimmed so that no more than ½ in. (13 mm) of a grip protrudes from the head of the testing machine.

A9.3.3 *Gauge Marks*— The 8-in. (200-mm) gauge length shall be marked on the specimen using a preset 8-in. (200-mm) punch or, alternately, may be punch marked every 2 in. (50 mm) along the 8-in. (200-mm) gauge length, on one of the longitudinal ribs, if present, or in clear spaces of the deformation pattern. The punch marks shall not be put on a transverse deformation. Light punch marks are desirable because deep marks severely indent the bar and may affect the results. A bullet-nose punch is desirable.

A9.3.4 The yield strength or yield point shall be determined by one of the following methods:

A9.3.4.1 Extension under load using an autographic diagram method or an extensometer as described in 13.1.2 and 13.1.3,

A9.3.4.2 By the drop of the beam or halt in the gauge of the testing machine as described in 13.1.1 where the steel tested as a sharp-kneed or well-defined type of yield point.

A9.3.5 The unit stress determinations for yield and tensile strength on full-size specimens shall be based on the nominal bar area.

A9.4 Bend Testing

A9.4.1 Bend tests shall be made on specimens of sufficient length to ensure free bending and with apparatus which provides:

A9.4.1.1 Continuous and uniform application of force throughout the duration of the bending operation,

A9.4.1.2 Unrestricted movement of the specimen at points of contact with the apparatus and bending around a pin free to rotate, and

A9.4.1.3 Close wrapping of the specimen around the pin during the bending operation.

A9.4.2 Other acceptable more severe methods of bend testing, such as placing a specimen across two pins free to rotate and applying the bending force with a fix pin, may be used.

A9.4.3 When retesting is permitted by the product specification, the following shall apply:

A9.4.3.1 Sections of bar containing identifying roll marking shall not be used.

A9.4.3.2 Bars shall be so placed that longitudinal ribs lie in a plane at right angles to the plane of bending.

A10. PROCEDURE FOR USE AND CONTROL OF HEAT-CYCLE SIMULATION

A10.1 Purpose

A10.1.1 To ensure consistent and reproducible heat treatments of production forgings and the test specimens that represent them when the practice of heat-cycle simulation is used.

A10.2 Scope

A10.2.1 Generation and documentation of actual production time—temperature curves (MASTER CHARTS).

A10.2.2 Controls for duplicating the master cycle during heat treatment of production forgings. (Heat treating within the essential variables established during A1.2.1).

A10.2.3 Preparation of program charts for the simulator unit.

A10.2.4 Monitoring and inspection of the simulated cycle within the limits established by the ASME Code.

A10.2.5 Documentation and storage of all controls, inspections, charts, and curves.

A10.3 Referenced Documents

A10.3.1 *ASME Standards*[5]:

ASME Boiler and Pressure Vessel Code Section III, latest edition.

ASME Boiler and Pressure Vessel Code Section VIII, Division 2, latest edition.

A10.4 Terminology

A10.4.1 *Definitions*:

A10.4.1.1 *master chart*—a record of the heat treatment received from a forging essentially identical to the production forgings that it will represent. It is a chart of time and temperature showing the output from thermocouples imbedded in the forging at the designated test immersion and test location or locations.

A10.4.1.2 *program chart*—the metallized sheet used to program the simulator unit. Time-temperature data from the master chart are manually transferred to the program chart.

A10.4.1.3 *simulator chart*—a record of the heat treatment that a test specimen had received in the simulator unit. It is a chart of time and temperature and can be compared directly to the master chart for accuracy of duplication.

A10.4.1.4 *simulator cycle*—one continuous heat treatment of a set of specimens in the simulator unit. The cycle includes heating from ambient, holding at temperature, and cooling. For example, a simulated austenitize and quench of a set of specimens would be one cycle; a simulated temper of the same specimens would be another cycle.

A10.5 Procedure

A10.5.1 *Production Master Charts*:

A10.5.1.1 Thermocouples shall be imbedded in each forging from which a master chart is obtained. Temperature shall be monitored by a recorder with resolution sufficient to clearly define all aspects of the heating, holding, and cooling process. All charts are to be clearly identified with all pertinent information and identification required for maintaining permanent records.

A10.5.1.2 Thermocouples shall be imbedded 180° apart if the material specification requires test locations 180° apart.

A10.5.1.3 One master chart (or two if required in accordance with A10.5.3.1) shall be produced to represent essentially identical forgings (same size and shape). Any change in size or geometry (exceeding rough machining tolerances) of a forging will necessitate that a new master cooling curve be developed.

A10.5.1.4 If more than one curve is required per master forging (180° apart) and a difference in cooling rate is achieved, then the most conservative curve shall be used as the master curve.

A10.5.2 *Reproducibility of Heat Treatment Parameters on Production Forgings*:

A10.5.2.1 All information pertaining to the quench and temper of the master forging shall be recorded on an appropriate permanent record, similar to the one shown in Table A10.1.

A10.5.2.2 All information pertaining to the quench and temper of the production forgings shall be appropriately recorded, preferably on a form similar to that used in A10.5.2.1. Quench records of production forgings shall be retained for future reference. The quench and temper record of the master forging shall be retained as a permanent record.

A10.5.2.3 A copy of the master forging record shall be stored with the heat treatment record of the production forging.

A10.5.2.4 The essential variables, as set forth on the heat treat record, shall be controlled within the given parameters on the production forging.

A10.5.2.5 The temperature of the quenching medium prior to quenching each production forging shall be equal to or lower than the temperature of the quenching medium prior to quenching the master forging.

A10.5.2.6 The time elapsed from opening the furnace door to quench for the production forging shall not exceed that elapsed for the master forging.

A10.5.2.7 If the time parameter is exceeded in opening the furnace door to beginning of quench, the forging shall be placed back into the furnace and brought back up to equalization temperature.

A10.5.2.8 All forgings represented by the same master forging shall be quenched with like orientation to the surface of the quench bath.

A10.5.2.9 All production forgings shall be quenched in the same quench tank, with the same agitation as the master forging.

A10.5.2.10 *Uniformity of Heat Treat Parameters*—*(1)* The difference in actual heat treating temperature between production forgings and the master forging used to establish the simulator cycle for them shall not exceed ±25°F (±14°C) for

TABLE A10.1 Heat-Treat Record-Essential Variables

	Master Forging	Production Forging 1	Production Forging 2	Production Forging 3	Production Forging 4	Production Forging 5
Program chart number						
Time at temperature and actual temperature of heat treatment						
Method of cooling						
Forging thickness						
Thermocouple immersion						
Beneath buffer (yes/no)						
Forging number						
Product						
Material						
Thermocouple location—0 deg						
Thermocouple location—180 deg						
Quench tank No.						
Date of heat treatment						
Furnace number						
Cycle number						
Heat treater						
Starting quench medium temperature						
Time from furnace to quench						
Heating rate above 1000°F (538°C)						
Temperature upon removal from quench after 5 min						
Orientation of forging in quench						

the quench cycle. *(2)* The tempering temperature of the production forgings shall not fall below the actual tempering temperature of the master forging. *(3)* At least one contact surface thermocouple shall be placed on each forging in a production load. Temperature shall be recorded for all surface thermocouples on a Time Temperature Recorder and such records shall be retained as permanent documentation.

A10.5.3 *Heat-Cycle Simulation*:

A10.5.3.1 Program charts shall be made from the data recorded on the master chart. All test specimens shall be given the same heating rate above, the AC1, the same holding time and the same cooling rate as the production forgings.

A10.5.3.2 The heating cycle above the AC1, a portion of the holding cycle, and the cooling portion of the master chart shall be duplicated and the allowable limits on temperature and time, as specified in (a)–(c), shall be established for verification of the adequacy of the simulated heat treatment.

(a) Heat Cycle Simulation of Test Coupon Heat Treatment for Quenched and Tempered Forgings and Bars—If cooling rate data for the forgings and bars and cooling rate control devices for the test specimens are available, the test specimens may be heat-treated in the device.

(b) The test coupons shall be heated to substantially the same maximum temperature as the forgings or bars. The test coupons shall be cooled at a rate similar to and no faster than the cooling rate representative of the test locations and shall be within 25°F (14°C) and 20 s at all temperatures after cooling begins. The test coupons shall be subsequently heat treated in accordance with the thermal treatments below the critical temperature including tempering and simulated post weld heat treatment.

(c) Simulated Post Weld Heat Treatment of Test Specimens (for ferritic steel forgings and bars)—Except for carbon steel (P Number 1, Section IX of the Code) forgings and bars with a nominal thickness or diameter of 2 in. (51 mm) or less, the test specimens shall be given a heat treatment to simulate any thermal treatments below the critical temperature that the forgings and bars may receive during fabrication. The simulated heat treatment shall utilize temperatures, times, and cooling rates as specified on the order. The total time at temperature(s) for the test material shall be at least 80 % of the total time at temperature(s) to which the forgings and bars are subjected during postweld heat treatment. The total time at temperature(s) for the test specimens may be performed in a single cycle.

A10.5.3.3 Prior to heat treatment in the simulator unit, test specimens shall be machined to standard sizes that have been determined to allow adequately for subsequent removal of decarb and oxidation.

A10.5.3.4 At least one thermocouple per specimen shall be used for continuous recording of temperature on an independent external temperature-monitoring source. Due to the sensitivity and design peculiarities of the heating chamber of certain equipment, it is mandatory that the hot junctions of control and monitoring thermocouples always be placed in the same relative position with respect to the heating source (generally infrared lamps).

A10.5.3.5 Each individual specimen shall be identified, and such identification shall be clearly shown on the simulator chart and simulator cycle record.

A10.5.3.6 The simulator chart shall be compared to the master chart for accurate reproduction of simulated quench in accordance with A10.5.3.2*(a)*. If any one specimen is not heat treated within the acceptable limits of temperature and time, such specimen shall be discarded and replaced by a newly machined specimen. Documentation of such action and reasons for deviation from the master chart shall be shown on the simulator chart, and on the corresponding nonconformance report.

A10.5.4 *Reheat Treatment and Retesting*:

A10.5.4.1 In the event of a test failure, retesting shall be handled in accordance with rules set forth by the material specification.

A10.5.4.2 If retesting is permissible, a new test specimen shall be heat treated the same as previously. The production forging that it represents will have received the same heat treatment. If the test passes, the forging shall be acceptable. If it fails, the forging shall be rejected or shall be subject to reheat treatment if permissible.

A10.5.4.3 If reheat treatment is permissible, proceed as follows: *(1)* Reheat treatment same as original heat treatment (time, temperature, cooling rate): Using new test specimens from an area as close as possible to the original specimens, repeat the austenitize and quench cycles twice, followed by the tempering cycle (double quench and temper). The production forging shall be given the identical double quench and temper as its test specimens above. *(2)* Reheat treatment using a new heat treatment practice. Any change in time, temperature, or cooling rate shall constitute a new heat treatment practice. A new master curve shall be produced and the simulation and testing shall proceed as originally set forth.

A10.5.4.4 In summation, each test specimen and its corresponding forging shall receive identical heat treatment or heat treatment; otherwise the testing shall be invalid.

A10.5.5 *Storage, Recall, and Documentation of Heat-Cycle Simulation Data*—All records pertaining to heat-cycle simulation shall be maintained and held for a period of 10 years or as designed by the customer. Information shall be so organized that all practices can be verified by adequate documented records.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 370 – 07) that may impact the use of this standard. (Approved June 1, 2007.)

(*1*) Section 9 was revised.

(*2*) Fig. 3 was revised.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 370 – 06) that may impact the use of this standard. (Approved April 1, 2007.)

(*1*) Corrected reference errors in Table A1.1.

(*2*) Revised test time for the Brinell hardness test.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 370 – 05) that may impact the use of this standard. (Approved November 1, 2006.)

(*1*) Wording change in 14.1.

Designation: A 369/A 369M – 06

Standard Specification for Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service[1]

This standard is issued under the fixed designation A 369/A 369M; 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 heavy-wall carbon and alloy steel pipe (Note 1) made from turned and bored forgings and is intended for high-temperature service. Pipe ordered under this specification shall be suitable for bending and other forming operations and for fusion welding. Selection will depend on design, service conditions, mechanical properties and high-temperature characteristics.

NOTE 1—The use of the word "pipe" throughout the several sections of this specification is used in the broad sense and intended to mean pipe headers, or leads.

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."

1.2 Several grades of ferritic steels are covered. Their compositions are given in Table 1.

1.3 Supplementary requirements (S1 to S6) 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.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

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

E 290 Test Methods for Bend Testing of Material for Ductility

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

2.2 *ASME Boiler and Pressure Vessel Code:*

Section 1X Welding Qualifications[4]

2.3 *ANSI Standard:*

B 46.1 Surface Texture[5]

3. Ordering Information

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

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

3.1.2 Name of material (forged and bored pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (inside diameter and minimum wall thickness),

3.1.5 Length (Permissible Variations in Length Section of Specification A 999/A 999M),

3.1.6 End finish (13),

3.1.7 Optional requirements (Sections 8, Supplementary Requirements S1 to S6; 13.2),

3.1.8 Test report required (Certification Section of Specification A 999/A 999M),

3.1.9 Specification designation, and

3.1.10 Special requirements or exceptions to this specification.

4. General Requirements

4.1 Material furnished under 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 *Discard*:

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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.

Current edition approved Sept. 1, 2006. Published September 2006. Originally approved in 1953. Last previous edition approved in 2002 as A 369/A 369M – 02.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-369 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, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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

TABLE 1 Chemical Requirements

Grade	Composition, %			
	FPA	FPB	FP1	FP2
Carbon	0.25 max	0.30 max	0.10–0.20	0.10–0.20
Manganese	0.27–0.93	0.29–1.06	0.30–0.80	0.30–0.61
Phosphorus, max	0.035	0.035	0.025	0.025
Sulfur, max	0.035	0.035	0.025	0.025
Silicon	0.10 min	0.10 min	0.10–0.50	0.10–0.30
Chromium	...	...	...	0.50–0.81
Molybdenum	...	...	0.44–0.65	0.44–0.65
Grade	FP5	FP9	FP11	FP12
Carbon	0.15 max	0.15 max	0.05–0.15	0.05–0.15
Manganese	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.61
Phosphorus, max	0.025	0.030	0.025	0.025
Sulfur, max	0.025	0.030	0.025	0.025
Silicon	0.50 max	0.50–1.00	0.50–1.00	0.50 max
Chromium	4.00–6.00	8.00–10.00	1.00–1.50	0.80–1.25
Molybdenum	0.45–0.65	0.90–1.10	0.44–0.65	0.44–0.65
Grade	FP21	FP22	FP91	FP92
Carbon	0.05–0.15	0.05–0.15	0.08–0.12	0.07–0.13
Manganese	0.30–0.60	0.30–0.60	0.30–0.60	0.30–0.60
Phosphorus, max	0.025	0.025	0.025	0.020
Sulfur, max	0.025	0.025	0.025	0.010
Silicon	0.50 max	0.50 max	0.20–0.50	0.50 max
Chromium	2.65–3.35	1.90–2.60	8.00–9.50	8.50–9.50
Molybdenum	0.80–1.06	0.87–1.13	0.85–1.05	0.30–0.60
			Others:	W 1.50–2.00
			Ni 0.40 max	V 0.15–0.25
			V 0.18–0.25	Cb 0.04–0.09
			Cb 0.06–0.10	N 0.030–0.070
			N 0.03–0.07	Ni 0.40 max
			Al 0.02 max	Al 0.02 max
			Ti 0.01 max	Ti 0.01 max
			Zr 0.01 max	Zr 0.01 max
				B 0.001–0.006

5.1.1 A sufficient discard shall be made from each ingot to secure freedom from injurious defects. The steel shall have a homogeneous structure.

5.2 *Manufacture*:

5.2.1 Material for forging shall consist of ingots or of blooms, billets, or solid-rolled bars forged or rolled from an ingot, and cut to the required length by a process that will not produce injurious defects in the forging.

5.2.2 The material shall be forged (Note 3) by hammering or pressing, and shall be brought as nearly as practicable to the finished shape and size by hot working.

NOTE 3—The cross-sectional area of the solid forging shall have a reduction by forging or by rolling and forging from that of the ingot in the ratio of not less than 3 to 1.

5.2.3 Unless otherwise specified, the final forging operation shall be followed by a treatment suitable to the grade as specified in 5.4.

5.3 *Machining*:

5.3.1 All forgings shall have both the inner and outer surfaces machined.

5.3.2 After heat treatment, the pipe shall be machined to a finish with a roughness value no greater than 250-µin. [6.4-µm] arithmetical average deviation (AA), terms as defined in ANSI B 46.1-1962, unless otherwise specified.

5.4 *Heat Treatment*:

5.4.1 All pipe of the grades shown in Table 1 other than FPA, FPB, FP1, FP2, FP12, FP91, and FP92 shall be reheated and furnished in the full-annealed or normalized and tempered condition. If furnished in the normalized and tempered condition (Note 4), the temperature for tempering shall be 1250 °F [680 °C] or higher for Grades FP5, FP9, FP21, and FP22, and 1200 °F [650 °C] or higher for Grades FP36 and FP11.

NOTE 4—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].

5.4.2 Pipe in Grades FPA and FPB as a final heat treatment shall be either normalized or shall be given a stress relieving treatment at 1200 to 1300 °F [650 to 705 °C]. Pipe in Grades FP1, FP2, and FP12, as a final heat treatment shall be given a stress-relieving treatment at 1200 to 1300 °F [650 to 705 °C].

NOTE 5—Certain of the ferritic steels covered by this specification tend to 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, hot-bending and other forming operations, should be followed by suitable heat treatment.

5.4.3 Except when Supplementary Requirement S6 is specified by the purchaser, Grade FP91 shall be normalized and tempered by reheating within the temperature range from 1900 to 1975 °F [1040 to 1080 °C], followed by air cooling and tempering in the temperature range of 1350 to 1470 °F [730 to 800 °C].

5.4.4 Except when Supplementary Requirement S6 is specified by the purchaser, Grade FP92 shall be normalized and tempered by reheating within the temperature range of 1900 to 1975 °F [1040 to 1080 °C], followed by air cooling and tempering in the temperature range of 1350 to 1470 °F [730 to 800 °C].

6. Chemical Composition

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

7. Heat Analysis

7.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the tubular product manufacturer, shall conform to the requirements specified.

7.2 In the case of large ingots poured from two or more heats, the weighted average of the chemical determinations of the several heats, made in accordance with 7.1, shall conform to the requirements specified in Section 6.

8. Product Analysis

8.1 At the request of the purchaser, a product analysis shall be made by the manufacturer on every heat.

8.2 The results of these analyses shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 6.

8.3 If the analysis of one of the tests specified in Section 7 or Section 8 does not conform to the requirements specified in Section 6 an analysis of each billet or pipe from the same heat may be made, and all billets or pipes conforming to the requirements shall be accepted.

9. Tensile Requirements

9.1 The material shall conform to the requirements as to tensile properties prescribed in Table 2. Tests for acceptance shall be made after final heat treatment of the forging.

10. Mechanical Tests Required

10.1 *Transverse or Longitudinal Tension Test*—One test shall be made on a specimen from one end of one length of pipe representing each heat in each heat-treatment lot.

10.2 *Flattening Test*—For pipe NPS 14 or less, and diameter to wall thickness ratios of more than 7.0, a flattening test shall be carried out in accordance with Specification A 999/A 999M. A test shall be carried out on a specimen taken from one end of each length of pipe.

10.3 *Bend Test*—For pipe larger than NPS 14 or NPS where diameters to wall thickness ratio is 7.0 or less, a bend test shall be carried out in accordance with Test Methods E 290. Unless otherwise specified, the test specimens shall be taken in a transverse direction. The diameter of the pin shall be ⅔ *t* for longitudinal specimens or 1⅓ *t* for transverse specimens, where *t* is the specimen thickness. The bend test specimens shall be bent at room temperature through 180° without cracking. One bend test shall be taken from one end of each length of pipe.

11. Workmanship

11.1 The pipe shall conform to the sizes and shapes specified by the purchaser.

12. Ends

12.1 Pipe ends shall be machined as specified in the purchase order.

13. Finish

13.1 The finished pipe shall be reasonably straight and shall have a workmanlike finish.

13.2 Repair of defects by welding shall be permitted only subject to the approval of the purchaser. Defects shall be thoroughly chipped or ground out before welding. Only qualified operators and procedures in accordance with the ASME Boiler and Pressure Vessel Code, Section IX, shall be used. Local or full heat treatment in accordance with 5.4 shall follow welding. Local grinding following welding and retreating shall be considered as meeting the requirements of 5.3.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 999/A 999M, the marking shall include the wall thickness, piece mark, length, and additional symbol "S" if the pipe conforms to the supplementary requirements specified in Supplementary Requirements S1 to S5, and the heat number or the manufacturer's number by which the heat can be identified. Indentation stamping, instead of stenciling, will be permitted only with the written approval of the purchaser.

TABLE 2 Tensile Requirements

Grade	FPA	FPB	FP1, FP2	FP12	FP91	FP92	All Others
Tensile strength, min; ksi [MPa]	48 [330]	60 [415]	55 [380]	60 [415]	85 [585]	90 [620]	60 [415]
Yield strength, min; ksi [MPa]	30 [210]	35 [240]	30 [210]	32 [220]	60 [415]	64 [440]	30 [210]

Grade	Elongation Requirements							
	FPA		FPB		FP91 and FP92		All Others	
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
Elongation in 2 in. or 50 mm, 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	35	25	30	17	27	18	30	20
When standard round 2-in. or 50-mm gage length test specimen is used	28	20	22	12	20	13	22	14

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Additional Tension Test

S1.1 An additional tension test shall be made on a specimen from one or each end of each pipe. If this supplementary requirement is specified, the number of tests per pipe required shall be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest.

S2. Additional Flattening or Bend Tests

S2.1 The appropriate flattening or bend test may be made on specimens from both ends of each length of pipe. Crop ends may be used. If the specimen from either end of any length fails to conform to the specific requirement, that length shall be rejected.

S3. Ultrasonic Tests

S3.1 Each pipe shall be ultrasonically tested to determine its soundness throughout the entire length of the pipe. Until suitable standards are established, the basis for rejection of material shall be a matter of agreement between the manufacturer and purchaser.

S4. Hydrostatic Test

S4.1 A hydrostatic pressure test shall be applied as agreed upon by the manufacturer and purchaser.

S5. Metal Structure and Etching Tests

S5.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S6. Alternative Heat Treatment—Grades FP91 and FP92

S6.1 Grades FP91 and FP92 shall be normalized in accordance with 5.4.3 or 5.4.4, respectively, and tempered at a temperature, to be specified by the purchaser, less than 1350 °F [730 °C]. It shall be the purchaser's responsibility to subsequently temper in the range of 1350 to 1470 °F [730 to 800 °C]. All mechanical tests shall be made on material heat treated in accordance with 5.4.3 or 5.4.4, respectively. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S6'' shall be included with the required marking of the pipe.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 369/A 369M – 02, that may impact the use of this specification. (Approved September 1, 2006)

(*1*) Revised 5.4.3, 5.4.4, and Supplementary Requirement S6 to reduce the maximum normalizing termperatures and to establish temperature ranges for tempering of Grades FP91 and FP92.

(*2*) Revised Table 1 to reduce maximum Al and establish maximums for Ti and Zr for Grades FP91 and FP92.

Standard Specification for Electric-Fusion-Welded Austenitic Chromium-Nickel Stainless Steel Pipe for High-Temperature Service and General Applications[1]

This standard is issued under the fixed designation A 358/A 358M; 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 electric-fusion-welded austenitic chromium-nickel stainless steel pipe suitable for corrosive or high-temperature service, or both, or for general applications.

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."

1.2 This specification covers the grades of alloy and stainless steel listed in Table 1. The selection of the proper grade and requirements for heat treatment shall be at the discretion of the purchaser, dependent on the service conditions to be encountered.

1.3 Five classes of pipe are covered as follows:

1.3.1 *Class 1*—Pipe shall be double welded by processes employing filler metal in all passes and shall be completely radiographed.

1.3.2 *Class 2*—Pipe shall be double welded by processes employing filler metal in all passes. No radiography is required.

1.3.3 *Class 3*—Pipe shall be single welded by processes employing filler metal in all passes and shall be completely radiographed.

1.3.4 *Class 4*—Same as Class 3 except that the weld pass exposed to the inside pipe surface may be made without the addition of filler metal (see 6.2.2.1 and 6.2.2.2).

1.3.5 *Class 5*—Pipe shall be double welded by processes employing filler metal in all passes and shall be spot radiographed.

1.4 Supplementary requirements covering provisions ranging from additional testing to formalized procedures for manufacturing practice are provided. Supplementary Requirements S1 through S6 are included as options to be specified when desired.

1.5 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:* [3]

A 240/A 240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A 994 Guide for Editorial Procedures and Form of Product Specifications for Steel, Stainless Steel, and Related Alloys

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

E 527 Practice for Numbering Metals and Alloys (UNS)

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

Section II, Materials

Section III, Rules for Construction of Nuclear Facility Components

Section VIII, Pressure Vessels

Section IX, Welding and Brazing Qualifications

2.3 *AWS Specifications:*[5]

A 5.22 Flux Cored Arc Welding

[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.

Current edition approved March 1, 2005. Published April 2005. Originally approved in 1952. Last previous edition approved in 2004 as A 358/A 358M – 04.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specifications SA-358 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, Three Park Ave., New York, NY 10016-5990.

[5] Available from The American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.

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

A 5.30 Consumable Weld Inserts for Gas Tungsten Arc Welding
A 5.4 Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes
A 5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes
A 5.11 Nickel and Nickel-Alloy Covered Welding Electrodes
A 5.14 Nickel and Nickel-Alloy Bare Welding Rods and Electrodes

2.4 *Other Standard:*[6]

SAE J1086 Practice for Numbering Metals and Alloys (UNS)

3. Terminology

3.1 *Definitions*:

3.1.1 The definitions in Specification A 999/A 999M and Terminology A 941 are applicable to this specification.

4. Ordering Information

4.1 It shall be the responsibility of the purchaser to specify all requirements that are necessary for product under this specification. Such requirements to be considered include, but are not limited to, the following:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (electric-fusion-welded pipe),

4.1.3 Grade (Table 1),

4.1.4 Class (see 1.3),

4.1.5 Size (outside diameter and nominal wall thickness),

4.1.6 Length (specific or random),

4.1.7 End finish (Section on Ends of Specification A 999/A 999M),

4.1.8 Authorization for repair of plate defects by welding and subsequent heat treatment without prior approval if such is intended (see 9.3),

4.1.9 Specification designation,

4.1.10 Special requirements,

4.1.11 Statement invoking requirements of 16.4 if such is intended.

4.1.12 Circumferential weld permissibility (see Section 16),

4.1.13 Supplementary Requirements (S1 through S6),

4.1.14 Applicable ASME Code if known,

4.1.15 For ASME Code Section III applications, the service classification intended, and

4.1.16 Certification requirements (see Section on Certification of Specification A 999/A 999M).

5. General Requirements

5.1 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.

6. Materials and Manufacture

6.1 *Materials*:

6.1.1 The steel plate material shall conform to the requirements of one of the grades of Specification A 240/A 240M, listed in Table 1, except as provided in 6.3.2.3.

6.2 *Welding*:

6.2.1 The joints shall be full penetration double-welded or single-welded butt joints employing fusion welding processes as defined under "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 rings or strips are employed, the ring or strip material shall be of the same P-Number (Table QW-422 of Section IX) 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 6.2.3. Welds made by procedures employing backing strips or rings that remain in place are prohibited. Welding procedures, and welding operators shall be qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

6.2.2 Except as provided in 6.2.2.1 and 6.2.2.2, welds shall be made in their entirety by processes involving the deposition of filler metal.

6.2.2.1 For Class 4 pipe employing multiple passes, the root-pass may be without the addition of filler metal.

6.2.2.2 For Class 4 pipe, the weld surface exposed inside the pipe may result from a single pass made from the inside of the pipe without the addition of filler metal.

6.2.2.3 All single-welded pipe shall be completely radiographed.

6.2.3 The weld surface on either side of the weld is permitted to be flush with the base plate or to have a reasonably uniform crown, not to exceed ⅛ in. [3 mm]. It is permitted at the option of the manufacturer or by agreement between the manufacturer and purchaser to remove any weld reinforcement. The contour of the reinforcement should 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.

6.2.4 Weld defects shall be repaired by removal to sound metal and rewelding. Subsequent heat treatment and examination (that is, visual, radiographic, and dye penetrant) shall be as required on the original welds.

6.3 *Heat Treatment*:

6.3.1 Unless otherwise stated in the order, all pipe shall be furnished in the heat-treated condition in accordance with the requirements of Table 2.

6.3.2 The purchase order shall specify one of the following conditions if the heat-treated condition specified in 6.3.1 is not desired by the purchaser:

6.3.2.1 *A final heat-treatment temperature under 1900 °F [1040 °C]*—Each pipe supplied under this requirement shall be stenciled with the final heat-treatment temperature in degrees Fahrenheit or degrees Celsius after the suffix "HT". Controlled structural or special service characteristics may be specified as a guide for the most suitable heat treatment.

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

TABLE 1 Plate and Filler Metal Specifications

Grade	UNS Desig-nation	Material, Type	ASTM Plate Specification No. and Grade	Filler Metal Classification and UNS Designation[A] for Applicable[B] AWS Specification											
				A 5.4		A 5.9		A 5.11		A 5.14		A 5.22		A 5.30	
				Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS	Class.	UNS
304	S30400	304	A 240 Type 304	E308	W30810	ER308	S30880 W30840	. . .	. . .	. . .	. . .	E308T	W30831	IN308	S30880
304L	S30403	304L	A 240 Type 304	E308L	W30813	ER308L	S30883 W30843	. . .	. . .	. . .	. . .	E308LT	W30835	IN308L	S30883
304N	S30451	304N	A 240 Type 304N	E308	W30810	ER308	S30880 W30840	. . .	. . .	. . .	. . .	E308T	W30831	IN308	S30880
304LN	S30453	304LN	A 240 Type 304LN	E308L	W30813	ER308L	S30883 W30843	. . .	. . .	. . .	. . .	W308LT	W30835	IN308L	S30883
304H	S30409	304H	A 240 Type 304H	E308H	W30810	ER308	S30880 W30840	. . .	. . .	. . .	. . .	E308T	W30831	IN308	S30880
309Cb	S30940	309Cb	A 240, Type 309Cb	E309Cb	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
309S	S30908	309S	A 240, Type 309S	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
310Cb	S31040	310Cb	A 240, Type 310Cb	E310Cb	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . ..	. . .	. . .	. . .
310S	S31008	310S	A 240, Type 310S	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
316	S31600	316	A 240 Type 316	E316	W31610	ER316	S31680 W31640	. . .	. . .	. . .	. . .	E316T	W31631	IN316	S31680
316L	S31603	316L	A 240 Type 316L	E316L	W31613	ER316L	S31683 W31643	. . .	. . .	. . .	. . .	E316LT	W31635	IN316L	S31683
316N	S31651	316N	A 240 Type 316N	E316	W31610	ER316	S31680 W31640	. . .	. . .	. . .	. . .	E316T	W31631	IN316	S31680
316LN	S31653	316LN	A 240 Type 316LN	E316L	W31613	ER316L	S31683 W31643	. . .	. . .	. . .	. . .	E316LT	W31635	IN316L	S31683
316H	S31609	316H	A 240 Type 316H	E316H	W31610	ER316H	S31680 W31640	. . .	. . .	. . .	. . .	E316T	W31631	IN316	S31680
317	S31700	317	A 240 Type 317	E317	W31710	ER 317	S31780 W31740	. . .	. . .	. . .	. . .	E317LT	W31735	. . .	. . .
317L	S31703	317L	A 240 Type 317L	E317L	W34713	ER317L	S31783 W31743	. . .	. . .	. . .	. . .	E317LT	W31735	. . .	. . .
321	S32100	321	A 240 Type 321	E347	W34710	ER321 ER347	S32180 W32140 S34780 W34740	. . .	. . .	. . .	. . .	E347T	W34733	IN348	S34780
321H[C]	S32109[C]	321H[C]	A 240 Type 321H[C]	E321H	W34710	ER321 ER347	S32180 W32140 S34780 W34740					E347T	W34731	IN348	S34780
347	S34700	347	A 240 Type 347	E347	W34710	ER347	S34780 W34740	. . .	. . .	. . .	. . .	E347T	W34733	IN348	S34780
347H[C]	S34709[C]	347H[C]	A 240 Type 347H[C]	E347H	E347H	W34710	ER347	S34780 W34740				E347T	W34731	IN348	S34780
348	S34800	348	A 240 Type 348	E347	W34710	ER347	S34780 W34740	. . .	. . .	. . .	. . .	E347T	W34733	IN348	S34780
XM-19	S22100	XM-19	A 240 Type XM-19	E209	W32210	ER209	S20980 W32240	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
XM-29	S28300	XM-29	A 240 Type XM-29	E240	W32410	ER240	S23980 W32440	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S31254	. . .	A 240 S31254	. . .	. . .	. . .	. . .	ENiCrMo-3	W86112	ERNiCrMo-3	N06625	. . .	. . .	. . .	. . .
. . .	S30815	. . .	A 240 S30815	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S31725	. . .	A 240 S31725	. . .	. . .	. . .	. . .	ENiCrMo-3	W86112	ERNiCrMo-3	N06625	. . .	. . .	. . .	. . .
. . .	S31726	. . .	A 240 S31726	. . .	. . .	. . .	. . .	ENiCrMo-3	W86112	ERNiCrMo-3	N06625	. . .	. . .	. . .	. . .
. . .	S30600[D]	. . .	A 240 S30600[D]	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S24565	. . .	A 240 S24565	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S30415	. . .	A 240 S30415	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S32654	. . .	A 240 S32654	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S31266	. . .	A 240 S31266	. . .	. . .	. . .	. . .	ENiCrMo–13	W86059	ERNiCrMo–13	N06059	. . .	. . .	. . .	. . .
. . .	S31266	. . .	A 240 S31266	. . .	. . .	. . .	. . .	ENiCrMo–10	W86022	ERNiCrMo–10	N06022	. . .	. . .	. . .	. . .
. . .	S32050	. . .	A 240 S32050	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	N08367	. . .	A 240 N08367	. . .	. . .	. . .	. . .	ENiCrMo-3	W86112	ERNiCrMo-3	N06625	. . .	. . .	. . .	. . .
. . .	N08904	. . .	A 240 N08904	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	N08926	. . .	A 240 N08926	. . .	. . .	. . .	. . .	ENiCrMo–3	W86112	ERNiCrMo–3	N06625	. . .	. . .	. . .	. . .
. . .	N08800	. . .	A 240 N08800	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	N08810	. . .	A 240 N08810	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	N08020	. . .	A 240 N08020	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
. . .	S20400	. . .	A 240 S20400	E 209	W32210	ER209	S20980 W32240	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

[A] New designation established in accordance with Practice E 527and SAE J 1086.
[B] Choice of American Welding Society specification depends on the welding process used.
[C] Minimum carbon content of the filler metal shall be 0.040 mass %.
[D] In previous editions, S30600 was incorrectly shown as S01815.

6.3.2.2 *No final heat treatment of pipe fabricated of plate that has been solution heat treated at temperatures required by this specification*—Each pipe supplied under this requirement shall be stenciled with the suffix “HT-O”.

6.3.2.3 *No final heat treatment of pipe fabricated of plate that has not been solution heat treated*—Each pipe supplied under this requirement shall be stenciled with the suffix “HT-SO”.

6.4 A solution annealing temperature above 1950 °F [1065 °C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in Grades 321, 321H, 347, 347H, and 348. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S5).

7. Chemical Composition

7.1 The chemical composition of the plate shall conform to the requirements of the applicable specification and grade listed in Specification A 240/A 240M.

7.2 The chemical composition of the welding filler metal shall conform to the requirements of the applicable AWS specification for the corresponding grade shown in Table 1, or shall conform to the chemical composition specified for the plate in Specification A 240/A 240M, or shall, subject to purchaser approval, be a filler metal more highly alloyed than the base metal when needed for corrosion resistance or other properties. Use of a filler metal other than that listed in Table 1 or conforming to the chemical composition specified for the plate in Specification A 240/A 240M shall be reported and the filler metal identified on the certificate of tests. When nitrogen and cerium are specified elements for the ordered grade, the method of analysis for these elements shall be a matter of agreement between the purchaser and the manufacturer.

8. Permissible Variations in Dimensions

8.1 *Permissible Variations*—The dimensions at any point in a length of pipe shall not exceed the following:

8.1.1 *Outside Diameter*—Based on circumferential measurement, ±0.5 % of the specified outside diameter.

8.1.2 *Out-of-Roundness*—Difference between major and minor outside diameters, 1 %.

8.1.3 *Alignment*—Using a 10-ft [3-m] straightedge placed so that both ends are in contact with the pipe, ⅛ in. [3 mm] deviation from contact with the pipe.

8.1.4 *Thickness*—The minimum wall thickness at any point in the pipe shall not be more than 0.01 in. [0.3 mm] under the nominal thickness.

9. Workmanship, Finish, and Appearance

9.1 The finished pipe shall have a workmanlike finish.

9.2 *Repair of Plate Defects by Machining or Grinding*—It is permitted to repair pipes showing slivers, or other surface defects, by machining or grounding inside or outside to a depth that ensures the removal of all included scale and slivers, provided that the wall thickness is not reduced below the specified minimum wall thickness. Machining or grinding shall follow inspection of the pipe as rolled, and shall be followed by supplementary visual inspection.

9.3 *Repair of Plate Defects by Welding*—It is permitted to repair by welding defects that violate minimum wall thickness, but only with the approval of the purchaser. Areas shall be suitably prepared for welding with tightly closed defects removed by grinding. Open, clean defects, such as pits or impressions, may require no preparation. All welders, welding operators, and weld procedures shall be qualified to the ASME Boiler and Pressure Vessel Code, Section IX. Unless the purchaser specifies otherwise, pipe required to be heat treated under the provisions of 6.3, shall be heat treated or reheat treated following repair welding. Repaired lengths, where repair depth is greater than ¼ of the thickness, shall be pressure tested or repressure tested after repair and heat treatment (if any). Repair welds shall also be examined by suitable non-destructive examination techniques, including any techniques specifically required of the primary weld.

9.4 The pipe shall be free of scale and contaminating iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser is permitted to request that a passivating treatment be applied.

10. Heat Analysis

10.1 An analysis of each heat of steel shall be made by the plate manufacturer to determine the percentages of the elements prescribed in Specification A 240/A 240M. The chemical composition thus determined shall conform to the requirements prescribed in Specification A 240/A 240M.

11. Product Analysis

11.1 For each lot of 500 ft [150 m] of pipe or fraction thereof, analysis shall be made by the manufacturer from the

TABLE 2 Annealing Requirements

Grade or UNS Designation[A]	Heat Treating Temperature[B]	Cooling/Testing Requirements
All grades not individually listed below:	1900 °F [1040 °C]	C
304H, 309S, 309Cb, 310S, 310Cb, 321H, 347H, S22100, S28300,	1900 °F [1040 °C]	D
N08020	1800-1850 °F [980-1010 °C]	D
N08367	2025 °F [1110 °C]	D
N08810	2050 °F [1120 °C]	D
N08904	2000 °F [1095 °C]	D
N08926	2010 °F [1100 °C]	D
S30600	2100 °F [1150 °C]	D
S30815	1920 °F [1050 °C]	D
S31254	2100 °F [1150 °C]	D
S31266	2100 °F [1150 °C]	D
S32050	2100 °F [1150 °C]	D
S32654	2100 °F [1150 °C]	D
S34565	2050 °F [1120 °C]	D

[A] New designation established in accordance with Practice E 527 and SAE J1086.
[B] Minimum, unless otherwise stated.
[C] Quenched in water or rapidly cooled by other means, at a rate sufficient to prevent reprecipitation of carbides, as demonstrable by the capability of passing Practices A 262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (see Supplementary Requirement S7). Note that Practices A 262 requires the test to be performed on sensitized specimens in the low-carbon and stabilized types and on specimens representative of the as-shipped condition for other types. In the case of low-carbon types containing 3 % or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and the purchaser.
[D] Quenched in water or rapidly cooled by other means.

finished pipe of the plate and of the weld deposit. Drillings for analysis may be taken from the mechanical test specimens. The results of these analyses shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements of Section 7, subject to the product analysis tolerances of Table 1 in Specification A 480/A 480M.

11.2 If the analysis of one of the tests specified in 9.1 does not conform to the requirements specified in Section 7, analyses shall be made on additional pipe of double the original number from the same lot, each of which shall conform to the requirements specified.

12. Tensile Requirements

12.1 The plate used in making the pipe shall conform to the requirements as to tensile properties of the applicable specifications listed in Table 1. Tension tests made by the plate manufacturer shall qualify the plate material.

12.2 The transverse tension test taken across the welded joint specimen shall have a tensile strength not less than the specified minimum tensile strength of the plate.

13. Transverse Guided-Bend Weld Tests

13.1 Two bend test specimens shall be taken transversely from the pipe. Except as provided in 13.2, one shall be subject to a face guided-bend test and the second to a root guided-bend test. One specimen shall be bent with the inside surface of the pipe against the plunger, and the other with the outside surface against the plunger.

13.2 For wall thicknesses over ⅜ in. [9.5 mm] but less than ¾ in. [19 mm] side-bend tests may be made instead of the face and root-bend tests. For specified wall thicknesses ¾ in. [19 mm] and over, both specimens shall be subjected to the side-bend tests. Side-bend specimens shall be bent so that one of the side surfaces becomes the convex surface of the bend specimen.

13.3 The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. [3 mm] in any direction is present in the weld metal or between the weld and the pipe metal after bending. Cracks that originate along the edges of the specimen during testing, and that are less than ¼ in. [6.5 mm] measured in any direction shall not be considered.

14. Test Specimens and Methods of Testing

14.1 Transverse tension and bend test specimens shall be taken from the end of the finished pipe; the transverse tension and bend test specimens shall be flattened cold before final machining to size.

14.2 As an alternative to the requirements of 14.1, it is permitted to take the test specimens from a test plate of the same material as the pipe that is attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

14.3 Tension test specimens shall be made 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.

14.3.1 Reduced-section specimens conforming to the requirements given in QW-462.1(b) may be used for tension tests on all thicknesses of pipe having outside diameter greater than 3 in. [76 mm].

14.3.2 Turned specimens conforming to the requirements of QW-462.1(d) may be used for tension tests.

14.3.2.1 If turned specimens are used as given in 14.3.2.2 and 14.3.2.3, one complete set shall be made for each required tension test.

14.3.2.2 For thicknesses to and including 1¼ in. [32 mm], it is permitted to use a single turned specimen.

14.3.2.3 For thicknesses over 1¼ in. [32 mm], multiple specimens shall be cut through the full thickness of the weld with their centers parallel to the material surface and not over 1 in. [25 mm] apart. The centers of the specimens adjacent to material surfaces shall not exceed ⅝ in. [16 mm] from the surface.

14.4 The test specimens shall not be cut from the pipe or test plate until after final heat treatment.

15. Mechanical Tests Required

15.1 For the purposes of the tension and bend test requirements, the term "lot" shall mean all pipe of the same grade, permitted to include more that one heat of steel, within a 3⁄16-in [4.7-mm] range of thickness and welded to the same weld procedure, and when heat treated, done so to the same heat-treating procedure and in the same furnace. The maximum lot size shall be 200 linear ft [60 m] of pipe.

15.1.1 *Transverse Tension Test*—One test shall be made to represent each lot of finished pipe.

15.1.2 *Transverse Guided-Bend Weld Test*—One test (two specimens) shall be made to represent each lot of finished pipe.

15.2 *Hydrostatic Test*—Each length of pipe shall be subjected to a hydrostatic test in accordance with Specification A 999/A 999M, unless specifically exempted under the provision of 15.3. Pressure shall be held for a sufficient time to permit the inspector to examine the entire length of the welded seam.

15.3 The purchaser, with the agreement of the manufacturer, is permitted to complete the hydrostatic test requirement with the system pressure test, performed at a pressure either lower or higher than the specification test pressure, but in no case shall the test pressure be lower than the system design pressure. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory marking the letters "NH."

16. Radiographic Examination

16.1 For Classes 1, 3, and 4 pipe, all welded joints shall be completely examined by radiography.

16.2 For Class 5 pipe, the welded joints shall be spot radiographed to the extent of not less than 12 in. [300 mm] of radiograph per 50 ft [15 m] of weld.

16.3 For Classes 1, 3, and 4 pipe, radiographic examination shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, latest edition, Paragraph UW-51.

16.4 For Class 5 pipe, radiographic examination shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest edition, Paragraph UW-52.

16.5 Radiographic examination is permitted to be performed prior to heat treatment.

17. Lengths

17.1 Circumferentially welded joints of the same quality as the longitudinal joints shall be permitted by agreement between the manufacturer and the purchaser.

18. Product Marking

18.1 In addition to the marking prescribed in Specification A 999/A 999M, the markings on each length of pipe shall include the plate material designations as shown in Table 1, the marking requirements of 6.3 and 15.3, and Class 1, 2, 3, or 4, as appropriate (see 1.3).

18.2 *Bar Coding*—In addition to the requirements in 18.1, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

19. Keywords

19.1 arc welded steel pipe; austenitic stainless steel; chromium-nickel steel; fusion welded steel pipe; high temperature application; steel pipe; temperature service applications; high; welded steel pipe

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser is permitted to specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, it is permitted to modify the retest and retreatment provisions of these supplementary requirements.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Tension and Bend Tests

S2.1 Tension tests (Section 12) and bend tests (Section 13) shall be made on specimens to represent each length of pipe. Failure of any test specimen to meet the requirements shall be cause for the rejection of the pipe length represented.

S3. Penetrant Oil and Powder Examination

S3.1 All welded joints shall be subjected to examination by a penetrant oil and powder method. The details of the method and the disposition of flaws detected shall be a matter for agreement between the purchaser and the manufacturer.

S4. Ferrite Control in Weld Deposits

S4.1 The ferrite content of the deposited weld metal in any length of pipe shall be determined. The procedural details pertaining to this subject (that is, welding; plate and weld deposit chemistry; testing equipment and method; number and location of test sites; and ferrite control limits) shall be a matter for agreement between the purchaser and the manufacturer.

S5. Stabilizing Heat Treatment

S5.1 Subsequent to the heat treatment required in 6.3, Grades 321, 321H, 347, 347H, and 348 shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and manufacturer.

S6. Intergranular Corrosion Test

S6.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S6.2 A stabilization heat treatment in accordance with Supplementary Requirement S5 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 358/A 358M – 04, that may impact the use of this specification. (Approved March 1, 2005)

(*1*) Added 317, 317L, 321H, and 347H to Table 1.
(*2*) Added Footnote ^{C} to Table 1.
(*3*) Added 321H and 347H to 6.4, Table 2, and Supplementary Requirement S2.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 358/A 358M – 01, that may impact the use of this specification. (Approved March 1, 2004)

(*1*) General revision for compliance with *Form and Style for ASTM Standards* and Guide A 994, and for consistency with Specification A 240/A 240M.

Designation: A 350/A 350M – 04a

Standard Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components[1]

This standard is issued under the fixed designation A 350/A 350M; 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*

1.1 This specification[2] covers several grades of carbon and low-alloy steel forged or ring-rolled flanges, forged fittings and valves intended primarily for low-temperature service and requiring notch toughness testing. They are made to specified dimensions, or to dimensional standards, such as the ASME and API Specifications referenced in Section 2. Although this specification covers some piping components machined from rolled bar and seamless tubular materials (see 5.3.3), it does not cover raw material produced in these product forms.

1.2 No limitation on size is intended beyond the ability of the manufacturer to obtain the specified requirements. However, Class 3 of Grade LF787 is only available in the quenched-and-precipitation heat treated condition.

1.3 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified by the purchaser in the order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 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.

NOTE 1—Refer to Test Methods and Definitions A 370 for notes on significance of notched-bar impact testing.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 788 Specification for Steel Forgings, General Requirements

A 961 Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

2.2 *ASME Standards:*

B 16.5 Steel Pipe Flanges and Flanged Fittings[4]

B 16.9 Factory-Made Wrought Steel Butt-Welding Fittings[4]

B 16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves[4]

B 16.11 Forged Steel Fittings, Socket-Welding and Threaded[4]

B 16.30 Unfired Pressure Vessel Flange Dimensions[4]

B 16.34 Valves-Flanged, Threaded, and Welding End[4]

B 16.47 Large Diameter Steel Flanges[4]

2.3 *ASME Boiler and Pressure Vessel Code:*

Section IX Welding Qualifications[2]

2.4 *AWS Standards:*

A 5.1 Mild Steel Covered Arc-Welding Electrodes[5]

A 5.5 Low-Alloy Steel Covered Arc-Welding Electrodes[5]

2.5 *API Standards:*[6]

600 Steel Gate Valves with Flanged or Butt-Welding Ends

602 Compact Design Carbon Steel Gate Valves for Refinery Use

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved October 1, 2004. Published October 2004. Originally approved in 1952. Last previous edition approved in 2004 as A 350/A 350M – 04.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-350 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, Three Park Ave., New York, NY 10016-5990.

[5] Available from The American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.

[6] Available from The American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005.

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

605 Large Diameter Carbon Steel Flanges

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order information necessary to purchase the needed material. In addition to the ordering information guidelines in Specification A 961, orders should include the following information:

3.1.1 The number of test reports required (see Section 14).

3.1.2 Additional requirements (see Table 1 footnotes).

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 961, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 961 constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 961, this specification shall prevail.

5. Manufacture

5.1 *Melting Process*—The steel shall be produced by any of the following primary processes: open-hearth, basic oxygen, electric-furnace, or vacuum-induction melting (VIM). The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting using electroslag remelting (ESR), or vacuum-arc remelting (VAR).

5.1.1 The steel shall be fully killed, fine-grain practice.

5.1.2 The molten steel may be vacuum treated prior to or during pouring of the ingot.

5.2 *Discard*—A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

5.3 *Forging Process*:

5.3.1 Material for forgings shall consist of ingots, or forged, rolled, or strandcast blooms, billets, slabs, or bars.

5.3.2 The finished product shall be a forging as defined in the Terminology section of Specification A 788.

5.3.3 Except for flanges of all types, hollow, cylindrically-shaped parts may be machined from rolled bar or seamless tubular materials provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Other parts, excluding flanges of all types, may be machined from hot-rolled or forged bar up through and including NPS4. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

5.4 *Heat Treatment*:

5.4.1 After hot working and before reheating for heat treatment, the forging shall be allowed to cool substantially below the transformation range.

5.4.2 Forgings of grades other than Grade LF787 shall be furnished in the normalized, or in the normalized and tempered, or in the quenched and tempered condition described by the following procedures:

5.4.2.1 *Normalize*—Heat to a temperature that produces an austenitic structure, holding sufficient time to attain uniform temperature throughout. Cool uniformly in still air.

5.4.2.2 *Normalize and Temper*—Subsequent to normalize, reheat to 1100 °F [590 °C] minimum, holding at temperature a minimum of 30 min/in. [30 min/25 mm] of maximum thickness, but in no case less than 30 min. Cool in still air.

5.4.2.3 *Quench and Temper*—The procedure for quenching shall consist of either (*1*) fully austenitizing the forgings followed by quenching in a suitable liquid medium or (*2*) using a multiple stage procedure whereby the forging is first fully austenitized and rapidly cooled, then reheated to partially reaustenitize, followed by quenching in a suitable liquid medium. All quenched forgings shall be tempered by reheating to a temperature between 1100 °F [590 °C] and the lower transformation temperature, holding at temperature a minimum of 30 min/in. [30 min/25 mm] of maximum thickness but in no case less than 30 min. Cool in still air.

5.4.3 Grade LF787 forgings shall be furnished in either the normalized-and-precipitation heat treated condition or in the quenched-and-precipitation heat treated condition. The heat treatment procedures shall be as follows:

5.4.3.1 *Normalized-and-Precipitation Heat Treated*—Heat to a temperature in the range from 1600 to 1725 °F [870 to 940 °C], hold at the temperature for a time sufficient to attain uniform temperature throughout, soak at the temperature for not less than ½ h, and remove from the furnace and cool in air. Subsequently, heat to a temperature in the range from 1000 to

TABLE 1 Chemical Requirements

Element	Composition, wt. %						
	Grade LF1	Grade LF2	Grade LF3	Grade LF5	Grade LF6	Grade LF9	Grade LF787
Carbon, max	0.30	0.30	0.20	0.30	0.22	0.20	0.07
Manganese	0.60–1.35	0.60–1.35	0.90 max	0.60–1.35	1.15–1.50	0.40–1.06	0.40–0.70
Phosphorus, max	0.035	0.035	0.035	0.035	0.025	0.035	0.025
Sulfur, max	0.040	0.040	0.040	0.040	0.025	0.040	0.025
Silicon[A]	0.15–0.30	0.15–0.30	0.20–0.35	0.20–0.35	0.15–0.30	...	0.40 max
Nickel	0.40 max[B]	0.40 max[B]	3.3–3.7	1.0–2.0	0.40 max[B]	1.60–2.24	0.70–1.00
Chromium	0.30 max[B,C]	0.30 max[B,C]	0.30 max[C]	0.30 max[C]	0.30 max[B,C]	0.30 max[C]	0.60–0.90
Molybdenum	0.12 max[B,C]	0.12 max[B,C]	0.12 max[C]	0.12 max[C]	0.12 max[B,C]	0.12 max[C]	0.15–0.25
Copper	0.40 max[B]	0.40 max[B]	0.40 max[C]	0.40 max[C]	0.40 max[B]	0.75–1.25	1.00–1.30
Columbium	0.02 max[D]	0.02 max[D]	0.02 max	0.02 max	0.02 max	0.02 max	0.02 min
Vanadium	0.08 max	0.08 max	0.03 max	0.03 max	0.04–0.11	0.03 max	0.03 max
Nitrogen	. . .	. . .	. . .	. . .	0.01–0.030	. . .	. . .

[A] When vacuum carbon-deoxidation is required by Supplementary Requirement S4, the silicon content shall be 0.12 % maximum.
[B] The sum of copper, nickel, chromium, vanadium and molybdenum shall not exceed 1.00 % on heat analysis.
[C] The sum of chromium and molybdenum shall not exceed 0.32 % on heat analysis.
[D] By agreement, the limit for columbium may be increased up to 0.05 % on heat analysis and 0.06 % on product analysis.

1200 °F [540 to 650 °C], soak at the temperature for not less than ½ h, and cool at any convenient rate.

5.4.3.2 *Quenched-and-Precipitation Heat Treated*—Heat to a temperature in the range from 1600 to 1725 °F [870 to 940 °C], hold at the temperature for a time sufficient to attain uniform temperature throughout, soak at the temperature for not less than ½ h and quench in a suitable liquid medium by immersion; reheat to a temperature in the range from 1000 to 1225 °F [540 to 665 °C], hold at the temperature for not less than ½ h, and cool at any convenient rate.

6. Chemical Composition

6.1 *Heat Analysis*:

6.1.1 A chemical heat analysis in accordance with Specification A 961 shall be made and conform to the requirements as to chemical composition prescribed in Table 1. Leaded steels shall not be permitted.

6.2 *Product Analysis*:

6.2.1 The purchaser may make a product analysis on products supplied to this specification in accordance with Specification A 961.

7. Mechanical Properties

7.1 *Tension Tests*:

7.1.1 *Requirements*—The material shall conform to requirements for tensile properties in Table 2.

7.1.1.1 The test specimen shall be obtained from a rough or finished forging, or prolongation thereof. For forgings under 10 000 lbs, at time of heat treatment, it may be obtained from separately forged test blanks from the same heat of steel as the production forgings. The test blank shall be reduced by forging in a manner similar to that for the products represented, and shall receive approximately the same hot working and reduction and the same heat treatment as the finished products represented. The test material shall be treated in the same furnace at the same time as the forging it represents, subject to the requirements of 7.1.2.1.

7.1.1.2 The test specimen shall represent all forgings from the same heat and heat-treatment load whose maximum thicknesses do not exceed the thickness of the test forging or blank by more than ¼ in. [6 mm].

7.1.2 *Number of Tests*—One tension test at room temperature shall be made in accordance with 7.1.1.2 from each heat in each heat-treatment load.

7.1.2.1 If heat treatment is performed in either a continuous or a batch-type furnace controlled within ±25 °F [±14 °C] of the required heat-treatment temperature and equipped with recording pyrometers so that complete records of heat treatment are available and if the same heat-treating cycles are used on the forgings represented by the tension test, then one tension test from each heat shall be required, instead of one tension test from each heat in each heat treatment load in accordance with 7.1.1.2.

7.1.3 *Test Locations and Orientations*—The test specimen shall be removed from the heaviest section of the forging or test blank, at locations described in 7.1.3.1, 7.1.3.2, 7.1.3.5 or as close to these locations as practical, subject to forging size and geometry.

7.1.3.1 For forgings or test blanks having a maximum heat-treated thickness, *T*, of 2 in. [50 mm] or less, the longitudinal axis of the test specimen shall be taken at mid-thickness and its mid-length shall be at least 2 in. [50 mm] from a second heat treated surface, exclusive of the *T* dimension surfaces. (This is normally referred to as ½ *T* by 2 in. [50 mm]).

7.1.3.2 For forgings or test blanks having a maximum heat-treated thickness, *T*, greater than 2 in. [50 mm], the central axis of the test specimen shall be taken at least ¼ *T* from the

TABLE 2 Tensile Properties at Room Temperature[A]

	Grades							
	LF1 and LF5 Class 1	LF2 Classes 1 and 2	LF3 Classes 1 and 2 LF5 Class 2	LF6		LF9	LF787	
				Class 1	Classes 2 and 3		Class 2	Class 3
Tensile strength, ksi [MPa]	60–85 [415–585]	70–95 [485–655]	70–95 [485–655]	66–91 [455–630]	75–100 [515–690]	63–88 [435–605]	65–85 [450–585]	75–95 [515–655]
Yield strength, min, ksi [MPa][B,C]	30 [205]	36 [250]	37.5 [260]	52 [360]	60 [415]	46 [315]	55 [380]	65 [450]
Elongation:								
Standard round specimen, or small proportional specimen, min % in 4D gage length	25	22	22	22	20	25	20	20
Strip specimen for wall thickness ⁵⁄₁₆ in. [7.94 mm] and over and for all small sizes tested in full section; min % in 2 in. [50 mm]	28	30	30	30	28	28	28	28
Equation for calculating min elongation for strip specimens thinner than ⁵⁄₁₆ in. [7.94 mm]; min % in 2 in. [50 mm] t = actual thickness in inches	48t + 13	48t + 15	48t + 15	48t + 15	48t + 13	48t + 13	48t + 13	48t + 13
Reduction of area, min, %	38	30	35	40	40	38	45	45

[A] See 7.3 for hardness tests.
[B] Determined by either the 0.2 % offset method or the 0.5 % extension under load method.
[C] For round specimens only.

nearest heat-treated surface and at least *T* or 4 in. [100 mm], whichever is less, from any second heat-treated surface. For quenched and tempered forgings, the midlength of the test specimen shall be at least *T* from any second heat-treated surface. See Fig. 1 for test specimen location in separately forged test blanks for quenched and tempered forgings.

7.1.3.3 *Metal Buffers*—The required distances from heat treated surfaces may be obtained with metal buffers instead of integral expansions. Buffer material may be carbon or low alloy steel, and shall be joined to the forging with a partial penetration weld that seals the buffered surface. Specimens shall be located at ½ in. [13 mm] minimum from the buffered surface of the forging. Buffers shall be removed and the welded areas subjected to magnetic particle test to assure freedom from cracks unless the welded areas are completely removed by subsequent machining.

7.1.3.4 The test specimen shall have its longitudinal axis located parallel to the direction of major working of the forging or test blank.

7.1.3.5 With prior purchaser approval, tests may be taken at a depth (*t*) corresponding to the distance from the area of significant loading to the nearest heat treated surface and at least twice this distance (2*t*) from any second surface. However, the test depth shall not be nearer to one treated surface than ¾ in. [19 mm] and to the second treated surface than 1½ in. [38 mm]. This method of test location would normally apply to contour-forged parts, or parts with thick cross-sectional areas where ¼ $T \times T$ testing (7.1.3.2) is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

7.1.4 *Test Method*—Testing shall be performed in accordance with Test Methods and Definitions A 370. The test specimen shall be as large as is practicable and shall be machined to the form and dimensions of Fig. 5 of Test Methods and Definitions A 370. When seamless tubular materials are used, testing shall be performed on longitudinal specimens in accordance with Annex A2, Steel Tubular Products, of Test Methods and Definitions A 370.

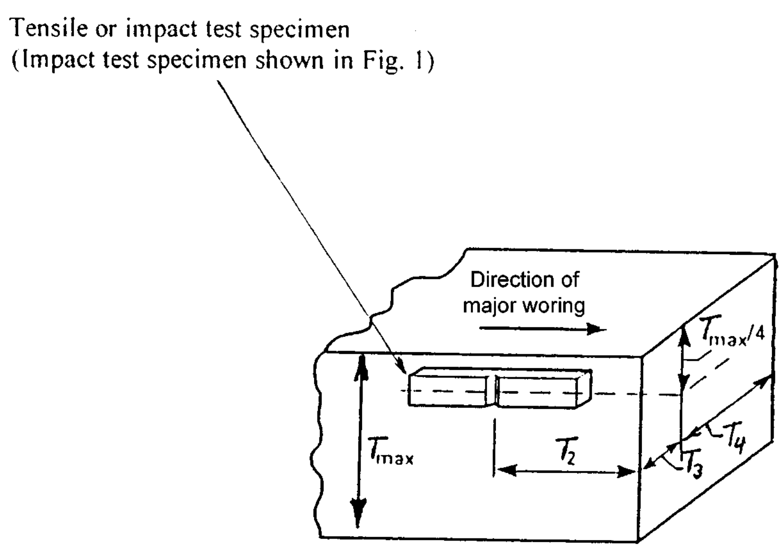
7.2 *Impact Test*:

7.2.1 *Requirements*—The material shall conform to the requirements for impact properties in Table 3 when tested at the applicable standard temperature in Table 4 within the limits of 7.2.4.2 and 7.2.4.3. When subsize specimens are used, the impact energy values obtained shall conform to Table 5 at energy values proportional to standard size. Exceptions to this requirement are permissible when Supplementary Requirement S1 is specified by the purchaser. Impact tests may be made at temperatures different from those in Table 4, provided that the test temperature is at least as low as the intended service temperature, and that the forging is suitably marked to identify the reported test temperature.

7.2.1.1 The test specimens shall be machined from material obtained as in 7.1.

7.2.2 *Number of Tests*—Three specimens shall constitute one test set. There shall be the same number of test sets as tension tests in 7.1.2.

7.2.3 *Test Locations and Orientations*—The test specimen shall be located and oriented as described in 7.1.3. The area under the notch of the impact test specimen shall be used to locate the specimen with respect to the second heat-treated surface. The base of the notch shall be perpendicular to the nearest heat-treated surface.



NOTE 1—For material with thickness *T* greater than 2 in. [50 mm],
$T_2 = T_3 = T_4 \geq T_{max}$
where:
T_{max} = maximum heat treated thickness

FIG. 1 Test Specimen Location for Quenched and Tempered Forgings

TABLE 3 Charpy V-Notch Energy Requirements for Standard Size [10 by 10 mm] Specimens

Grade	Minimum Impact Energy Required for Average of Each Set of Three Specimens, ft·lbf[J]	Minimum Impact Energy Permitted for One Specimen only of a Set, ft·lbf[J]
LF1 and LF9	13 [18]	10 [14]
LF2, Class 1	15 [20]	12 [16]
LF3, Class 1	15 [20]	12 [16]
LF5 Class 1 and 2	15 [20]	12 [16]
LF787 Classes 2 and 3	15 [20]	12 [16]
LF6, Class 1	15 [20]	12 [16]
LF2, Class 2	20 [27]	15 [20]
LF3, Class 2	20 [27]	15 [20]
LF6, Classes 2 and 3	20 [27]	15 [20]

TABLE 4 Standard Impact Test Temperature for Standard Size [10 by 10 mm] Specimens

Grade	Test Temperature, °F [°C]
LF1	−20 [−29]
LF2 Class 1	−50 [−46]
LF2 Class 2	−0 [−18]
LF3, Classes 1 and 2	−150 [−101]
LF5, Classes 1 and 2	−75 [−59]
LF6, Classes 1 and 2	−60 [−51]
LF6, Class 3	0 [−18]
LF9	−100 [−73]
LF787, Class 2	−75 [−59]
LF787 Class 3	−100 [−73]

TABLE 5 Minimum Equivalent Absorbed Energy ft·lbf (J) for Various Specimen Sizes[A]

Standard Size [10 by 10 mm]	¾ size [10 by 7.5 mm]	⅔ size [10 by 6.6 mm]	½ size [10 by 5 mm]	⅓ size [10 by 3.3 mm]	¼ size [10 by 2.5 mm]
15 [20]	12 [16]	10 [14]	8 [11]	5 [7]	4 [6]
13 [18]	10 [14]	9 [12]	7 [10]	5 [7]	4 [6]
12 [16]	10 [14]	9 [12]	7 [10]	4 [6]	3 [5]
10 [14]	8 [11]	7 [10]	5 [7]	3 [5]	3 [5]

[A] Straight-line interpolation for intermediate values is permitted.

7.2.4 *Test Method*—The notched bar impact test shall be made in accordance with the procedure for the Charpy V-notch type test as described in Test Methods and Definitions A 370.

7.2.4.1 Standard size specimens shown in Fig. 11 of Test Methods and Definitions A 370 shall be used for the impact test. Where the material is of insufficient thickness, or the shape of the forging precludes standard size, the largest obtainable subsize specimen described in Test Methods and Definitions A 370 shall be used.

7.2.4.2 Where subsize specimens are used and represent forged material with thicknesses equal to or greater than 0.394 in. [10 mm], and where the largest obtainable specimen has a width along the notch of at least 8 mm, such specimen shall be tested at the temperature in Table 4. Where the largest obtainable specimen has a width along the notch less than 8 mm, the temperature for testing shall be lower than the temperature in Table 4 by the amount shown in Table 6 for the actual specimen width tested.

7.2.4.3 Where subsize specimens are used and represent forged material with thicknesses less than 0.394 in. [10 mm], and where the largest obtainable specimen has a width along the notch of at least 80 % of the forging thickness, the specimen shall be tested at the temperature in Table 4. Where the largest obtainable specimen has a width along the notch of less than 80 % of the material thickness, the temperature for testing shall be lower than the temperature in Table 4 by an amount equal to the difference (referring to Table 6) between the temperature reduction corresponding to the thickness of the material represented, and the temperature reduction corresponding to the specimen width actually tested.

TABLE 6 Charpy Impact Test Temperature Reduction Below Table 4 Test Temperature when the Subsize Charpy Impact Width along Notch is Less than 80% of the Forging Thickness

Size of Bar	Thickness of the Material Represented (see 7.2.4.3), or Charpy, Impact Specimen Width Along the Notch[A], in. [mm]	Temperature Reduction, °F [°C]
Standard	0.394 [10]	0 [0]
Standard	0.354 [9]	0 [0]
Standard	0.315 [8]	0 [0]
¾-size	0.295 [7.5]	5 [3]
¾-size	0.276 [7]	8 [5]
⅔-size	0.262 [6.67]	10 [6]
⅔-size	0.236 [6]	15 [8]
½-size	0.197 [5]	20 [11]
½-size	0.158 [4]	30 [17]
⅓-size	0.131 [3.33]	35 [20]
⅓-size	0.118 [3]	40 [22]
¼-size	0.099 [2.5]	50 [28]

[A] Straight-line interpolation for intermediate values is permitted.

7.3 *Hardness Test*:

7.3.1 Except when only one forging is produced, a minimum of two forgings shall be hardness tested per batch or continuous run as defined in 7.1.2.1 to ensure that hardness of the forgings does not exceed 197 HB after heat treatment for mechanical properties. The hardness measurements shall be made in accordance with Test Methods and Definitions A 370. When only one forging is produced, it shall be hardness tested to ensure that it meets the 197 HB maximum of this specification. The purchaser may verify that this requirement has been met by testing at any location on the forging, provided that such testing does not render the forging useless.

8. Hydrostatic Test

8.1 Forgings manufactured under this specification shall be capable of passing a hydrostatic test compatible with the rating of the finished item. Such tests shall be conducted by the manufacturer only when Supplementary Requirement S57 of Specification A 961 is specified.

9. Workmanship, Finish, and Appearance

9.1 Forgings shall conform to the requirements of Specification A 961.

10. Retests

10.1 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

11. Rework and Retreatment

11.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings represented, and shall retest to the applicable requirements.

11.2 Individually tested forgings meeting all requirements shall be acceptable.

11.3 *Repair by Welding*—Weld repairs shall be permitted (see Supplementary Requirement S58 of Specification A 961) at the discretion of the manufacturer with the following limitations and requirements:

11.3.1 Repair by welding shall be made using welding procedures and welders qualified in accordance with ASME Section IX of the Code. The weld procedure qualification test shall also include impact tests of the weld metal and heat-affected zone. All impact test specimens shall have the longitudinal axis transverse to the weld and the base of the notch normal to the weld surface. Weld specimens shall have the notch in weld metal and heat-affected zone specimens shall have the notch in the heat-affected zone. The specimens shall be as large as permitted by the weldment thickness. Where full-size specimens can be obtained and where there is sufficient weldment thickness, the weld specimen shall be taken with one side of the specimen within 1⁄16 in. [1.6 mm] of the weld surface. Heat-affected zone impact test specimens shall be taken at the same depth and locations applicable to the forging in 7.1.3.1 and 7.1.3.2. When forgings are thermally treated after repair welding, the weld procedure test plate shall be subjected to the same thermal treatment. The mechanical properties of the weld procedure qualification test shall conform to Section 7.

11.3.2 Defects shall be completely removed by chipping or grinding to sound metal as verified by magnetic particle, or liquid penetrant inspection prior to welding.

11.3.3 For Grade LF1 forgings, and LF2 forgings that are to be only stress-relieved after repair welding, the weld metal shall be deposited using carbon steel electrodes E 7015, E 7016, or E 7018, complying with AWS A 5.1. For Grade LF2 forgings in all other conditions of post-weld heat treatment, the weld metal shall be deposited using low-alloy steel electrodes E 7015-A1; E 7016-A1, or E 7018-A1 complying with AWS 5.5; for Grade LF3 forgings the weld metal shall be deposited using low-alloy steel electrodes E 8016-C2 or E 8018-C2 complying with AWS A 5.5; for Grades LF5, LF9, and LF787 forgings, the weld metal shall be deposited using low-alloy steel electrodes E 8016-C1 or E 8018-C1 complying with AWS A 5.5. For Grade LF6, the electrodes shall be low-hydrogen, E-XX15, E-XX16, or E-XX18 complying with AWS A 5.1 or A 5.5, as applicable.

11.3.4 After repair welding, the area welded shall be completely free of defects as verified by magnetic particle or liquid penetrant inspection.

11.3.5 Forgings repair welded in the normalized, normalized and tempered, or the quenched and tempered conditions shall be stress-relieved after repair welding at 1100 °F [590 °C] minimum, but not higher than the temperature previously used for tempering the base metal of the same forging, or shall be reheat treated in accordance with 5.4.

11.3.6 When the purchaser specifies Supplementary Requirement S5, the same requirements shall apply to the weld procedure qualification tests.

11.3.7 Repair by welding shall not exceed 10 % of the surface area of the forging or 33⅓ % of the wall thickness of the finished forging, or ⅜ in. [9.5 mm], whichever is less, without prior approval of the purchaser.

11.3.8 When approval of the purchaser is obtained, the limitations set forth in 11.3.7 may be exceeded, but all other requirements of 11.3 shall apply.

12. Inspection

12.1 Inspection provisions of Specification A 961 shall apply.

13. Rejection and Rehearing

13.1 Purchaser shall comply with provisions of Specification A 961.

14. Certification

14.1 Test reports are required and they shall include certification that all requirements of this specification have been met, and shall be traceable to the forging represented. The specification designation included on test reports shall include year of issue and revision letter, if any. The manufacturer shall provide the following where applicable:

14.1.1 Type heat treatment, Section 5,

14.1.2 Chemical analysis results, Section 6 (Table 1),

14.1.3 Product analysis results, 6.2 (Table 1),

14.1.4 Tensile property results, Section 7 (Table 2) report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent,

14.1.5 Impact test results, 7.2 (Table 3, Table 4, Table 5, and Table 6),

14.1.6 Hardness results, 7.3.1,

14.1.7 Any supplementary testing required by the purchase order, and

14.1.8 If repaired by welding, letter W is to follow the ASTM designation.

15. Product Marking

15.1 In addition to the marking requirements of Specification A 961, manufacturer's name (see Note 2) or symbol shall be permanently marked on each forging.

NOTE 2—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

15.1.1 If the forgings have been quenched and tempered or quenched-and-precipitation heat treated, the letters QT shall be stamped on the forgings following the ASTM designation.

15.1.2 Forgings repaired by welding shall be marked with the letter W following the ASTM designation.

15.2 If identification stamps are objectionable and detrimental to the forging, and when so stated on the purchase order, the marks may be painted or stenciled on the forging, or stamped on a metal or plastic tag which shall be securely attached to the forging.

15.3 When test reports are required, additional marks shall be used as necessary to identify the part with the test report.

15.4 If the test temperature is other than the standard temperature specified in Table 4, the mark shall also include the suffix letter S to the grade and class and the test temperature. A prefix 0 to the test temperature shall indicate a less than 0 °F [-18 °C] value. For example, LF2S 0175 denotes a test temperature of –175 °F [-115 °C] for an LF2 part.

15.5 Parts meeting all requirements for more than one class may be marked with more than one class such as LF2 CL1/C12; LF5 CL1/CL2, and so forth.

15.6 *Bar Coding*—In addition to the requirements in 15.1, 15.2, 15.3, 15.4, and 15.5, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

16. Keywords

16.1 carbon equivalent; pipe fittings, steel; piping applications; pressure containing parts; steel flanges; steel forgings, alloy; steel forgings, carbon; steel valves; temperature service applications, low

SUPPLEMENTARY REQUIREMENTS

In addition to any supplementary requirements of Specification A 961, the following supplementary requirements shall apply only when specified by the purchaser in the order:

S1. Other Impact Test Temperatures

S1.1 Impact test temperatures lower or higher than the standard temperature in Table 4 of this specification shall be used.

S1.1.1 When higher test temperatures are employed, the actual test temperature may not be higher than that given in Table S1.1.1.

S1.2 The test temperature shall be specified by the purchaser. When subsize specimens are used, the manufacturer shall adjust the test temperature in accordance with the size restrictions of 7.2.4.2 and 7.2.4.3.

S1.3 The forging shall be marked with the specified test temperature in accordance with 15.4. A lower temperature shall not be marked on the forging because of the use of subsize specimens.

S1.4 The test results shall comply with Table 3 for standard size specimens, and with Table 5 for subsize specimens.

S2. Stress-Relieved Test Specimens

S2.1 The test specimens shall be stress relieved. Stress relieving shall be done after heat treatment in 5.4 and before machining the specimens from the heat-treated test material.

S2.2 The purchaser shall furnish the forging manufacturer with details of the stress-relief treatment desired.

TABLE S1.1.1 Maximum Supplemental Test Temperatures

Grade	Maximum Test Temperature, °F [°C]
LF1	−10 [−23]
LF2, Class 1	−35 [−37]
LF3, Classes 1 and 2	−125 [−87]
LF5, Classes 1 and 2	−60 [−51]
LF6, Classes 1 and 2	−40 [−40]
LF9	−80 [−62]
LF787, Class 2	−60 [−51]
LF787, Class 3	−80 [−62]
LF2 Class 2	+10 [−12]
LF6 Class 3	+10 [−12]

S3. Lateral Expansion

S3.1 Lateral expansion of the Charpy V-notch test in accordance with Section 25 of Test Methods and Definitions A 370 shall be measured and reported.

S4. Vacuum Carbon-Deoxidized Steels

S4.1 Material made to Grades LF1, LF2, LF3, LF5, and LF9 shall be vacuum carbon-deoxidized, in which case the silicon content shall be 0.12 % maximum. The test report shall indicate that the steel was vacuum carbon-deoxidized.

S5. Special Impact Test Requirements for Flanges (Note S5.1)

S5.1 Charpy test specimens shall be cut from an actual flange representing each size, heat, and heat-treatment lot. If more than one size flange is represented by the same heat and heat-treatment lot, the maximum size flange shall be considered representative.

S5.2 The number, location, and orientation of the test specimens shall be stated on the order.

S5.3 The test results shall comply with Table 3 for standard size specimens, and with Table 5 for subsize specimens.

NOTE S5.1—These special requirements should be considered for services when the applied stresses approach the maximum permissible limits of the governing code, or the installation is subject to severe cyclic conditions (7000 or more cycles over the expected life of the installation), or both.

S6. Carbon Equivalent

S6.1 The maximum carbon equivalent based on heat analysis shall be as shown in Table S6.1.

S6.2 Determine the carbon equivalent (CE) as follows:

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

S6.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

TABLE S6.1 Maximum Carbon Equivalent Value

Grade	Max.Thickness Less Than or Equal to 2 in.	Max. Thickness Greater Than 2 in.
LF1	0.45	0.46
LF2 CL1 and CL2	0.47	0.48
LF6 CL1	0.45	0.46
LF6 CL2	0.47	0.48

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 350/A 350M – 04, that may impact the use of this specification. (Approved October 1, 2004)

(*1*) Deleted paragraph 6.1.2 and revised Sections 3 and 14.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 350/A 350M – 02b, that may impact the use of this specification. (Approved March 1, 2004)

(*1*) Revised Grades LF1 and LF2 in Table 1 to allow higher Cb by agreement.

Designation: A 335/A 335M – 06

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*

1.1 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:* [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)
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]
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:

3.1.1 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),
3.1.5 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),

[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.

Current edition approved May 1, 2006. Published May 2006. Originally approved in 1951. Last previous edition approved in 2005 as A 335/A 335M-05a.

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

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

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

***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 0.02 max Cb 0.06–0.10 Ti 0.01 max Zr 0.01 max
P92	K92460	0.07–0.13	0.30–0.60	0.020	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 0.02 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	0.020	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 0.020 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 0.060–0.10 B 0.0003–0.006 N 0.04–0.09 Al 0.02 max W 0.90–1.10 Ti 0.01 max Zr 0.01 max

[A] New designation established in accordance with Practice E 527 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.

3.1.8 Optional requirements (Section 8, 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*:

5.3.1 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].

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.

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].

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].

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 3.

9.2 Table 4 lists elongation requirements.

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

9.4 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	Equation[B]
Longitudinal, all grades except P23, P91, P92, P122, and P911	$E = 48t + 15.00$ $[E = 1.87t + 15.00]$
Transverse, all grades except P23, P91, P92, P122, and P911	$E = 32t + 10.00$ $[E = 1.25t + 10.00]$
Longitudinal, P23, P91, P92, P122, and P911	$E = 32t + 10.00$ $[E = 1.25t + 10.00]$
Longitudinal, P36	$E = 32t + 5.0$ $[E = 1.25t + 5.0]$

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

10. Permissible Variations in Diameter

10.1 For pipe ordered to NPS [DN] or outside diameter, variations in outside diameter shall not exceed those specified in Table 6.

10.2 For pipe ordered to inside diameter, the inside diameter shall not vary more than ± 1 % from the specified inside diameter.

11. Permissible Variations in Wall Thickness

11.1 In addition to the implicit limitation of wall thickness for pipe imposed by the limitation on weight in Specification A 999/A 999M, the wall thickness for pipe at any point shall be within the tolerances specified in Table 7. The minimum wall thickness and outside diameter for inspection for compliance with this requirement for pipe ordered by NPS [DN] and schedule number is shown in ASME B36.10M.

12. Hydrostatic Test

12.1 Each length of pipe shall be subjected to the hydrostatic test, except as provided for in 12.2 or 12.3.

TABLE 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	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 4 Elongation Requirements

Elongation Requirements	All grades except P23, P36 P91, P92, P122, and P911		P23, P91, P92, P122, and P 911		P36
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal
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 5 gives the calculated minimum values.

12.2 Unless otherwise specified in the purchase order, each length of pipe shall, at the option of the manufacturer, be subjected to the nondestructive electric test as shown in Section 13 in lieu of the hydrostatic test.

12.3 When specified by the purchaser, pipe shall be furnished without hydrostatic test and without nondestructive examination.

12.4 When specified by the purchaser, pipe shall be furnished with both the hydrostatic test and a nondestructive examination having been performed.

13. Nondestructive Examination

13.1 When selected by the manufacturer or when specified in the order, as an alternative to the hydrostatic test (12.2), or when specified in the purchase order in addition to the hydrostatic test (12.4), each pipe shall be examined by a nondestructive examination method in accordance with Practice E 213, Practice E 309 or Practice E 570. The range of pipe sizes that may be examined by each method shall be subject to the limitations in the scope of the respective practices.

13.2 The following information is for the benefit of the user of this specification:

13.2.1 The reference standards defined in 13.8 are convenient standards for standardization of nondestructive examination equipment. The dimensions of these standards should not be construed as the minimum size imperfection detectable by such equipment.

13.2.2 Ultrasonic examination can be performed to detect both longitudinally and transversely oriented discontinuities. It should be recognized that different techniques should be employed to detect differently oriented imperfections. The examination may not detect short, deep imperfections.

13.2.3 The eddy current examination referenced in this specification has the capability to detect significant discontinuities, especially of the short abrupt type.

13.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. It should be recognized that different techniques should be employed to detect differently oriented imperfections.

13.2.5 The hydrostatic test of Section 12 has the capability to find imperfections of a size that permit the test fluid to leak through the pipe wall so that it may be either visually seen or detected by a loss of fluid pressure. This test may not detect very tight, through-wall imperfections, or imperfections that extend into the wall without complete penetration.

13.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular products.

13.3 *Time of Examination*:

Nondestructive examination for specification acceptance shall be performed after all mechanical processing, heat treatments and straightening operations. This requirement does not preclude additional testing at earlier stages in the processing.

13.4 *Surface Conditions*:

13.4.1 All surfaces shall be clean and free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of test results. The methods used for cleaning and preparing the surfaces for examination shall not be detrimental to the base metal or the surface finish.

13.4.2 Excessive surface roughness or deep scratches can produce signals that interfere with the test (see 13.10.2.3).

13.5 *Extent of Examination*:

13.5.1 The relative motion of the pipe and the transducer(s), coil(s), or sensor(s) shall be such that the entire pipe surface is scanned, except for end effects as noted in 13.5.2.

13.5.2 The existence of end effects is recognized, and the extent of such effects shall be determined by the manufacturer, and, if requested, shall be reported to the purchaser. Other nondestructive tests may be applied to the end areas, subject to agreement between the purchaser and the manufacturer.

13.6 *Operator Qualifications*—The test unit operator shall be certified in accordance with SNT-TC-1A, or an equivalent, recognized and documented standard.

13.7 *Test Conditions*:

13.7.1 For examination by the ultrasonic method, the minimum nominal transducer frequency shall be 2.25 MHz.

13.7.2 For eddy current testing, the excitation coil frequency shall be 10 kHz, or less.

13.8 *Reference Standards*:

13.8.1 Reference standards of convenient length shall be prepared from a length of pipe of the same grade, size (NPS or outside diameter and schedule or wall thickness), surface finish and heat treatment condition as the pipe to be examined.

13.8.2 For ultrasonic testing, the reference notches shall be any one of the three common notch shapes shown in Practice E 213, at the option of the manufacturer. The depth of the notch

TABLE 5 Calculated Minimum Elongation Values

Wall Thickness		Elongation in 2 in. or 50 mm, min, %			
		All grades except P23, P36, P91, P92, P122, and P911		P23, P91, P92, P122, and P911	P36
in.	mm	Longi-tudinal	Transverse	Longi-tudinal	Longi-tudinal
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

TABLE 6 Permissible Variations in Outside Diameter

NPS [DN] Designator	Over		Under	
	in.	mm	in.	mm
1⁄8 to 1½ [6 to 40], incl.	1⁄64 (0.015)	0.40	1⁄64 (0.015)	0.40
Over 1½ to 4 [40 to 100], incl.	1⁄32 (0.031)	0.79	1⁄32 (0.031)	0.79
Over 4 to 8 [100 to 200], incl.	1⁄16 (0.062)	1.59	1⁄32 (0.031)	0.79
Over 8 to 12 [200 to 300], incl.	3⁄32 (0.093)	2.38	1⁄32 (0.031)	0.79
Over 12 [300]	± 1 % of the specified outside diameter			

TABLE 7 Permitted Variations in Wall Thickness

NPS [DN] Designator	Tolerance, % from Specified	
	Over	Under
1⁄8 to 2½ [6 to 65] incl., all t/D ratios[A]	20.0	12.5
Above 2½ [65], t/D ≤ 5 %[A]	22.5	12.5
Above 2½ [65], t/D > 5 %[A]	15.0	12.5

[A] t = Specified Wall Thickness; D = Specified Outside Diameter.

shall not exceed 12½ % of the specified nominal wall thickness of the pipe or 0.004 in. (0.1 mm), whichever is greater. The length of the notch shall be at least twice the diameter of the transducer(s). The width of the notch shall not exceed the depth.

13.8.3 For eddy current testing, the reference standard shall contain, at the option of the manufacturer, any one of the following discontinuities:

13.8.3.1 *Drilled Hole*—The reference standard shall contain three or more holes, equally spaced circumferentially around the pipe and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the pipe wall, with care being taken to avoid distortion of the pipe while drilling. The hole diameter shall vary with NPS as follows:

NPS Designator	Hole Diameter
½	0.039 in. (1 mm)
above ½ to 1¼	0.055 in. (1.4 mm)
above 1¼ to 2	0.071 in. (1.8 mm)
above 2 to 5	0.087 in. (2.2 mm)
above 5	0.106 in. (2.7 mm)

13.8.3.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼ in. (6.4 mm) diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. Said notch shall have a depth not exceeding 12½ % of the specified nominal wall thickness of the pipe or 0.004 in. (0.1 mm), whichever is greater.

13.8.3.3 *Longitudinal Notch*—A notch 0.031 in. or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12½ % of the specified nominal wall thickness of the pipe or 0.004 in. (0.1 mm), whichever is greater. The length of the notch shall be compatible with the testing method.

13.8.4 For flux leakage testing, the longitudinal reference notches shall be straight-sided notches machined in a radial plane parallel to the pipe axis. For wall thickness less than ½ in. (12.7 mm), outside and inside notches shall be used; for wall thicknesses equal to or greater than ½ in., only an outside notch shall be used. Notch depth shall not exceed 12½ % of the specified nominal wall thickness or 0.004 in. (0.1 mm), whichever is greater. Notch length shall not exceed 1 in. (25.4 mm), and the width shall not exceed the depth. Outside and inside notches shall have sufficient separation to allow distinct identification of the signal from each notch.

13.8.5 More or smaller reference discontinuities, or both, may be used by agreement between the purchaser and the manufacturer.

13.9 *Standardization Procedure:*

13.9.1 The test apparatus shall be standardized at the beginning and end of each series of pipes of the same size (NPS or diameter and schedule or wall thickness), grade and heat treatment condition, and at intervals not exceeding 4 h during the examination of such pipe. More frequent standardizations may be performed at the manufacturer's option or may be required upon agreement between the purchaser and the manufacturer.

13.9.2 The test apparatus shall also be standardized after any change in test system settings, change of operator, equipment repair, or interruption due to power loss, shutdown or operator breaks.

13.9.3 The reference standard shall be passed through the test apparatus at same speed and test system settings as the pipe to be tested.

13.9.4 The signal-to-noise ratio for the reference standard shall be 2.5 to 1 or greater and the reference signal amplitude for each discontinuity shall be at least 50 % of full scale of the display.

13.9.5 If upon any standardization, the reference signal amplitude has decreased by 25 % (2 db), the test apparatus shall be considered out of standardization. The test system settings may be changed, or the transducer(s), coil(s) or sensor(s) adjusted, and the unit restandardized, but all pipe tested since the last acceptable standardization must be retested.

13.10 *Evaluation of Imperfections:*

13.10.1 Pipes producing a signal equal to or greater than the signal produced by the reference standard shall be positively identified and they shall be separated from the acceptable pipes. The area producing the signal may be reexamined.

13.10.2 Such pipes shall be subject to one of the following three dispositions:

13.10.2.1 The pipes may be rejected without further examination, at the discretion of the manufacturer.

13.10.2.2 The pipes shall be rejected, but may be repaired, if the test signal was produced by imperfections which cannot be identified, or was produced by cracks or crack-like imperfections. These pipes may be repaired by grinding (in accordance with 7.2.1), welding (in accordance with 7.6) or sectioning (in accordance with 7.2.3). To be accepted, a repaired pipe must pass the same nondestructive examination by which it was rejected, and it must meet the remaining wall thickness requirements of this specification.

13.10.2.3 Such pipes may be evaluated in accordance with the provisions of Section 7, if the test signals were produced by visual imperfections such as those listed below:

(*1*) Scratches,
(*2*) Surface roughness,
(*3*) Dings,
(*4*) Straightener marks,
(*5*) Cutting chips,
(*6*) Steel die stamps,
(*7*) Stop marks, or
(*8*) Pipe reducer ripple.

14. Mechanical Tests Required

14.1 *Transverse or Longitudinal Tension Test and Flattening Test, Hardness Test, or Bend Test*—For material heat treated in a batch-type furnace, tests shall be made on 5 % of the pipe from each treated lot (see Note 7). For small lots, at least 1 pipe shall be tested. For material heat treated by the continuous process, tests shall be made on a sufficient number of pipe to constitute 5 % of the lot (see Note 7), but in no case less than 2 pipe.

NOTE 7—The term "lot" applies to all pipe of the same nominal size and wall thickness (or schedule) which is produced from the same heat of steel and subjected to the same finishing treatment in a continuous furnace; when final heat treatment is in a batch-type furnace, the lot shall include only that pipe which is heat treated in the same furnace charge.

14.2 *Hardness Test*:

14.2.1 For pipe of Grades P91, P92, P122, P911, and P36, Brinell, Vickers, or Rockwell hardness tests shall be made on a specimen from each lot (see Note 7).

14.3 *Bend Test*:

14.3.1 For pipe whose diameter exceeds NPS 25 and whose diameter to wall thickness ratio is 7.0 or less shall be subjected to the bend test instead of the flattening test. Other pipe whose diameter equals or exceeds NPS 10 may be given the bend test in place of the flattening test subject to the approval of the purchaser.

14.3.2 The bend test specimens shall be bent at room temperature through 180° without cracking on the outside of the bent portion. The inside diameter of the bend shall be 1 in. [25 mm].

14.3.3 Test specimens for the bend test specified in 14.3 shall be cut from one end of the pipe and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either ½ by ½ in. [12.5 by 12.5 mm] in section or 1 by ½ in. [25 by 12.5 mm] in section with the corners rounded to a radius not over 1⁄16 in. [1.6 mm] and need not exceed 6 in. [150 mm] in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe, respectively.

15. Certification

15.1 In addition to the information required by Specification A 999/A 999M, the certification shall state whether or not the pipe was hydrostatically tested. If the pipe was nondestructively examined, the certification shall so state and shall show which practice was followed and what reference discontinuities were used. In addition, the test method information as given in Table 8 shall be appended to the specification number and grade shown on the certification.

16. Product Marking

16.1 In addition to the marking prescribed in Specification A 999/A 999M, the marking shall include the length, an additional symbol "S", if the pipe conforms to any of the Supplementary Requirements S1 to S6, the schedule number, if the pipe is ordered to a schedule number, and the heat number

TABLE 8 Test Method Information for Certification and Marking

Hydrostatic	Nondestructive	Marking
YES	NO	Test Pressure
NO	YES	NDE
NO	NO	NH
YES	YES	Test Pressure/NDE

or manufacturer's number by which the heat can be identified. Furthermore, the marking designated in Table 8 to indicate the test method(s) shall be included. Marking may be by stenciling, stamping, or rolling. Pipe that has been weld repaired in accordance with 7.6 shall be marked "WR."

17. Government Procurement

17.1 *Scale Free Pipe*:

17.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry contract or order, for agencies of the U.S. Government where scale free pipe is required. These requirements shall take precedence if there is a conflict between these requirements and the product specification.

17.1.2 The requirements of Specification A 999/A 999M for pipe shall be applicable when pipe is ordered to this specification.

17.1.3 Pipe shall be one of the following grades as specified herein:

Grade	UNS Designation
P11	K11597
P22	K21590
P5	K41545

17.1.4 *Part Number*:

17.1.4.1 Pipe shall be ordered to nominal pipe size and schedule specified in ASME B36.10M

Example: A 335/A 335M Pipe P-11 NPS 12 Sch 40

Specification Number	ASTM A 335/A 335M
Pipe	P
Grade	P-11
NPS	12
Wall	0.375

17.1.4.2

Specification Number	ASTM A 335/A 335 M
Tube	T
Grade	P-11
Outside Diameter	0.250
Wall	0.035

17.1.5 *Ordering Information*—Orders for material under this specification shall include the following in addition to the requirements of Section 3:

17.1.5.1 Pipe or tube,

17.1.5.2 Part number,

17.1.5.3 Ultrasonic inspection, if required,

17.1.5.4 If shear wave test is to be conducted in two opposite circumferential directions, and

17.1.5.5 Level of preservation and packing required.

18. Keywords

18.1 alloy steel pipe; high temperature service; seamless steel pipe; steel pipe; temperature service applications

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Tests

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 and over. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound. The bend test of 13.2 shall be substituted for the flattening test for pipe whose diameter exceeds NPS 25 and whose diameter to wall thickness ratio is 7.0 or less.

S4. Metal Structure and Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

NOTE S4.1—Pending development of etching methods applicable to the product covered by this specification, it is recommended that the Recommended Practice for a Standard Macro Etch Test for Routine Inspection of Iron and Steel, described in the *Metals Handbook*, Am. Soc. for Metals, 1948 edition, p. 389, be followed.

S5. Photomicrographs

S5.1 When requested by the purchaser and so stated in the order, the manufacturer shall furnish one photomicrograph at 100 diameters from a specimen of pipe in the as-finished condition for each individual size and wall thickness from each heat, for pipe NPS 3 and over. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, and heat. No photomicrographs for the individual pieces purchased shall be required except as specified in Supplementary Requirement S6. Such photomicrographs are for information only, to show the actual metal structure of the pipe as finished.

S6. Photomicrographs for Individual Pieces

S6.1 In addition to the photomicrographs required in accordance with Supplementary Requirement S5, the purchaser may specify that photomicrographs shall be furnished from each end of one or more pipes from each lot of pipe NPS 3 and larger in the as-finished condition. The purchaser shall state in the order the number of pipes to be tested from each lot. When photomicrographs are required on each length, the photomicrographs from each lot of pipe in the as-finished condition which may be required under Supplementary Requirement S5 may be omitted. All photo-micrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S7. Alternative Heat Treatment—Grade P91

S7.1 Grade P91 shall be normalized in accordance with Table 2 and tempered at a temperature, to be specified by the purchaser, less than 1350 °F [730 °C]. It shall be purchaser's responsibility to subsequently temper at 1350-1470 °F [730-800 °C] minimum. All mechanical tests shall be made on material heat treated in accordance with Table 2. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S7" shall be included with the required marking of the pipe.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 335/A 335M-05a, that may impact the use of this specification. (Approved May 1, 2006)

(*1*) Reduced Cr maximum for Grade 122 in Table 1.

(*2*) Reduce Al maximum and added maximums for Ti and Zr for Grades P91, P92, P122, and P911 in Table 1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 335/A 335M-05, that may impact the use of this specification. (Approved May 1, 2005)

(*1*) Revised Table 1, Table 3, Table 4, and Table 5 and modified 9.3 and 13.2.1 to provide for new grade P36, Classes 1 and 2.

(*2*) Revised 5.3, Supplementary Requirement S7, and added Table 2, to tabularize the heat treatment requirements and to provide ranges of normalizing and tempering temperatures for Grades P23, P91, P92, P911, and P122. Added permission to use quenching and tempering for P911 over 3 in. [75mm] in thickness.

(*3*) Added 7.6.1 and 7.6.2 to require post-weld heat treatment (PWHT) after weld repair, and to specify temperature ranges for PWHT, for Grades P23, P91, P92, P911, and P122.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 335/A 335M-03, that may impact the use of this specification. (Approved March 1, 2005)

(*1*) Added ASME B36.10M to Referenced Documents and corrected the reference from ANSI B36.10 to ASME B36.10M in 17.1.4.1.

(*2*) Revised Chromium content of Grade P911 in Table 1.

(*3*) Added DN SI-unit designator to 10.1 and Table 6.

(*4*) Added new Section 11 and Table 7 to address maximum wall thickness of pipe and renumbered subsequent paragraphs and tables accordingly.

Designation: A 334/A 334M – 04a

Standard Specification for Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service[1]

This standard is issued under the fixed designation A 334/A 334M; 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 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 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 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:* [3]

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

[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.

Current edition approved May 1, 2004. Published June 2004. Originally approved in 1951. Last previous edition approved in 2004 as A 334/A 334M – 04.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-334 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.

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

TABLE 1 Chemical Requirements

Element	Composition, %						
	Grade 1[A]	Grade 3	Grade 6[A]	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

[A]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.

°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

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

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.

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 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*D*), 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		30		30		30		22		28		18[A]	
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	28		22		22		22		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 points	1.75[B]		1.50[B]		1.50[B]		1.50[B]		1.25[B]		1.50[B]		...	

[A] Elongation of Grade 11 is for all walls and for small sizes tested in full section.
[B] The following table gives the calculated minimum values:

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

[A] Calculated elongation requirements shall be rounded to the nearest whole number.
Note—The above table 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 shown above, the minimum elongation value is determined by the following equations:

Grade	Equation[A]
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]

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

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[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.

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 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 ½ 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

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[A]		Temperature Reduction, Degrees Colder	
Inches	Millimetres	°F	°C
0.394	10 (standard size)	0	0
0.354	9	0	0
0.315	8	0	0
0.295	7.5 (3 / 4 standard size)	5	3
0.276	7	8	4
0.262	6.67 (2 / 3 standard size)	10	5
0.236	6	15	8
0.197	5 (1 / 2 standard size)	20	11
0.158	4	30	17
0.131	3.33 (1 / 3 standard size)	35	19
0.118	3	40	22
0.099	2.5 (1 / 4 standard size)	50	28

[A] Straight line interpolation for intermediate values is permitted.

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 S 1 is specified.

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 (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, A 334/A 334M – 04, that may impact the use of this specification. (Approved May 1, 2004)

(*1*) Moved Notes 2 and 3 into new Section 9 defining the sampling requirements.

(*2*) Renumbered subsequent sections and deleted all references to Notes 2 and 3 throughout.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 334/A 334M – 99, that may impact the use of this specification. (Approved March 1, 2004)

(*1*) Replaced Specification A 450/A 450M with Specification A 1016/A 1016M in sections 2, 3, 4, 15, and 16.

Designation: A 333/A 333M – 05

Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service[1]

This standard is issued under the fixed designation A 333/A 333M; 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*

1.1 This specification[2] covers nominal (average) wall seamless and welded carbon and alloy steel pipe intended for use at low temperatures. 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 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.

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.

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]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

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

A 671 Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures

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 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 A 999/A 999M),

3.1.6 End finish (see the Ends section of Specification A 999/A 999M),

3.1.7 Optional requirements, (see the Heat Analysis requirement in the Chemical Composition section of A 999/A 999M, the Repair by Welding section, and the section on Nondestructive Test Requirements),

3.1.8 Test report required, (see the Certification section of Specification A 999/A 999M),

3.1.9 Specification designation, and

3.1.10 Special requirements or exceptions to this specification.

4. Materials and Manufacture

4.1 *Manufacture*—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, see Specification A 671.

4.2 *Heat Treatment*:

4.2.1 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:

[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.

Current edition approved March 1, 2005. Published March 2005. Originally approved in 1950. Last previous edition approved in 2004 as A 333/A 333M – 04a.

[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.

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

TABLE 1 Chemical Requirements

Element	Composition, %								
	Grade 1[A]	Grade 3	Grade 4	Grade 6[A]	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	0.31–0.64	0.50–1.05	0.29–1.06	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	...	2.03–2.57	8.40–9.60	1.60–2.24	0.25 max	35.0–37.0
Chromium	...	...	0.44–1.01	...	...	...	...	0.15 max	0.50 max
Copper	...	...	0.40–0.75	...	...	...	0.75–1.25	0.15 max	...
Aluminum	...	...	0.04–0.30	...	...	...	...	0.06 max	...
Vanadium, max	...	...	...	...	...	...	...	0.12	...
Columbium, max	...	...	...	...	...	...	...	0.05	...
Molybdenum, max	...	...	...	...	...	...	...	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.

4.2.1.1 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.

4.2.1.2 Normalize as in 4.2.1.1, and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

4.2.1.3 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].

4.2.1.4 Treat as in 4.2.1.3 and, at the discretion of the manufacturer, reheat to a suitable tempering temperature.

4.2.1.5 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 4.2.1.

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

4.2.2.1 *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.

4.2.2.2 *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.

4.2.3 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].

4.2.4 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.

4.2.5 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 2, and then furnace cooled at a temperature not exceeding 600 °F [315 °C]. Grade 8 shall be 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.

TABLE 2 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].

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 3.

8. Impact Requirements

8.1 For Grades 1, 3, 4, 6, 7, 9, and 10, 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 4. The impact test is not required for Grade 11.

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 A 370.

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 in single random lengths of 16 to 22 ft (Note 3) with 5 % 12 to 16 ft (Note 3), or in double random lengths with a minimum average of 35 ft (Note 3) and a minimum length of 22 ft (Note 3) with 5 % 16 to 22 ft (Note 3).

NOTE 3—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 1⁄16 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 A 999/A 999M.

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 A 999/A 999M unless otherwise provided herein.

TABLE 3 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
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	
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	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
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	$E = 56t + 17.50$ [$E = 2.19t + 17.50$]
	Transverse	$E = 40t + 12.50$ [$E = 1.56t + 12.50$]
3	Longitudinal	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32t + 10.00$ [$E = 1.25t + 10.00$]
4	Longitudinal	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32t + 6.50$ [$E = 1.25t + 6.50$]
6	Longitudinal	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32t + 6.50$ [$E = 1.25t + 6.50$]
7	Longitudinal	$E = 48t + 15.00$ [$E = 1.87t + 15.00$]
	Transverse	$E = 32t + 11.00$ [$E = 1.25t + 11.00$]
8 and 10	Longitudinal	$E = 40t + 9.50$ [$E = 1.56t + 9.50$]
9	Longitudinal	$E = 48t + 13.00$ [$E = 1.87t + 13.00$]

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

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

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.

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 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.

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 5.

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, and 10 shall be lower than the minimum temperature shown in Table 5 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 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 E 23.

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

TABLE 5 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

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.

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 A 999/A 999M.

15.3 *Nondestructive Electric Test*—Nondestructive electric tests shall be in accordance with Specification A 999/A 999M, 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 A 999/A 999M, 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 Pipe shall be provided in the normalized heat-treated condition.

S2.2 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].

S2.3 The carbon equivalent shall be determined using the following formula:

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

S2.4 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 %.

S2.5 Based upon heat analysis in mass percent, the sum of the nickel and copper contents shall not exceed 0.15 %.

S2.6 Based upon heat analysis in mass percent, the carbon content shall not be less than 0.18 %.

S2.7 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.

S2.8 The designation “HF-N” 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 5 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 in 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, A 333/A 333M – 04a, that may impact the use of this specification. (Approved March 1, 2005)

(*1*) Removed old paragraph 12.3 and renumbered subsequent paragraphs.

(*2*) Added Supplementary Requirement S2 for HF acid alkylation service.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 333/A 333M – 04, that may impact the use of this specification. (Approved May 1, 2004)

(*1*) Replaced all references to Note 4 in 9.1 with Note 3.

(*2*) Revised Section 13 to incorporate Note 4 into the text.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 333/A 333M – 99, that may impact the use of this specification. (Approved March 1, 2004)

(*1*) Replaced Specification A 530/A 530M with Specification A 999/A 999M in the Referenced Documents.

(*2*) Replaced Specification A 530/A 530M with Specification A 999/A 999M in Sections 3, 11, 15, and 16.

(*3*) Extensively revised Section 15.

Designation: A 320/A 320M – 07a

Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service[1]

This standard is issued under the fixed designation A 320/A 320M; 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*

1.1 This specification[2] covers alloy steel bolting materials for pressure vessels, valves, flanges, and fittings for low-temperature service. The term "bolting material" as used in this specification covers rolled, forged, or strain hardened bars, bolts, screws, studs, and stud bolts. The bars shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be solution annealed or annealed and strain-hardened. When strain hardened austenitic stainless steel is ordered, the purchaser should take special care to ensure that Appendix X1 is thoroughly understood.

1.2 Several grades are covered, including both ferritic and austenitic steels designated L7, B8, etc. Selection will depend on design, service conditions, mechanical properties, and low-temperature characteristics. The mechanical requirements of Table 1 indicate the diameters for which the minimum mechanical properties apply to the various grades and classes, and Table 2 stipulates the requirements for Charpy impact energy absorption. The manufacturer should determine that the material can conform to these requirements before parts are manufactured. For example, when Grade L43 is specified to meet the Table 2 impact energy values at −150 °F [−101 °C], additional restrictions (such as procuring a steel with lower P and S contents than might normally be supplied) in the chemical composition for AISI 4340 are likely to be required.

NOTE 1—The committee formulating this specification has included several grades of material that have been rather extensively used for the present purpose. Other compositions will be considered for inclusion by the committee from time to time as the need becomes apparent. Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtainable.

1.3 Nuts for use with this bolting material are covered in Section 10 and the nut material shall be impact tested.

1.4 Supplementary Requirements (S1, S2, and S3) of an optional nature are provided. They shall apply only when specified in the inquiry, contract and order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 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.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range

E 566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals

F 436 Specification for Hardened Steel Washers

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved Sept. 1, 2007. Published October 2007. Originally approved in 1948. Last previous edition approved in 2007 as A 320/A 320M-07.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-320 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.

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

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets

2.2 *ANSI Standards:*

B1.1 Screw Threads[4]

B18.22.1 Plain Washers[4]

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order all information necessary to purchase the needed materials. Examples of such information include, but are not limited to, the following:

3.1.1 Quantity and size,

3.1.2 Heat-treated condition, that is, for the austenitic stainless steels, solution-treated (Class 1); solution-treated after finishing (Class 1A); and annealed and strain-hardened (Class 2),

3.1.3 Description of items required (bars, bolts, screws, or studs),

3.1.4 Nuts and washers, if required by the purchaser, in accordance with Section 10, and

3.1.5 Special requirements, in accordance with 5.1.1, 5.1.2, 5.1.3, and 12.1.

4. Common Requirements

4.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include methods, finish, thread dimensions, marking certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between the requirements in this specification and Specification A 962/A 962M, this specification shall prevail.

4.2 For L7M bolting, the final heat treatment, which may be the tempering operation if conducted at 1150 °F [620 °C] minimum, shall be done after machining and forming operations, including thread rolling and any type of cutting.

5. Materials and Manufacture

5.1 *Heat Treatment*:

5.1.1 The bolting material shall be allowed to cool to room temperature after rolling or forging. Grades L7, L7A, L7B, L7C, L7M, L43, L1, L70, L71, L72, and L73 shall be reheated to above the upper critical temperature and liquid quenched and tempered. Grades B8, B8C, B8M, B8T, B8F, B8P, B8LN, and B8MLN shall receive a carbide solution treatment. Products made from such material are described as Class 1. This shall consist of holding the material for a sufficient time at a temperature at which the chromium carbide will go into solution and then cooling in air or in a liquid medium at a rate sufficient to prevent reprecipitation of the carbide. Material thus treated is described as Class 1. If specified in the purchase order, material shall be solution treated in the finished condition; material so treated is described as Class 1A.

5.1.2 When increased mechanical properties are desired, the austenitic bolting materials shall be solution annealed and strain hardened if specified in the purchase order; material so treated is identified as Class 2.

5.1.3 If scale-free bright finish is required, this shall be specified in the purchase order.

5.1.4 For L7M bolting, the final heat treatment, which may be the tempering or stress-relieving operation conducted at 1150 °F [620 °C] minimum, shall be done after machining or rolling of the threads and any type of cutting.

6. Mechanical Requirements

6.1 *Tensile Properties*:

6.1.1 The material as represented by the tension specimens shall conform to the requirements as to tensile properties prescribed in Table 1 at room temperature after heat treatment (see 5.1.1). Alternatively, Class 2 Strain Hardened Headed Fasteners shall be tested full size after strain hardening to determine tensile strength and yield strength and shall conform to the requirements prescribed in Table 1. Should the results of full size tests conflict with results of tension specimen tests, full size test results shall prevail.

6.1.2 *Number of Tests*:

6.1.2.1 For heat-treated bars, one tension test and one impact test consisting of three specimens shall be made for each diameter of each heat represented in each tempering charge. In the continuous type treatment, a charge shall be defined as 6000 lb [2700 kg].

6.1.2.2 For studs, bolts, screws, etc., one tension test and one set of three impact specimens shall be made for each diameter of each heat involved in the lot. Each lot shall consist of the following:

Diameter, in. [mm]	Lot Size, lb [kg]
1⅛ [30] and under	1500 [680] or fraction thereof
Over 1⅛ [30] to 1¾ [45], incl	4500 [2040] or fraction thereof
Over 1¾ [45] to 2½ [65], incl	6000 [2700] or fraction thereof
Over 2½ [65]	100 pieces or fraction thereof

6.1.2.3 *Full Size Specimens, Headed Fasteners*—Headed fasteners 1 ½ in. in body diameter and smaller, with body length three times the diameter or longer, and which are produced by upsetting or forging (hot or cold) shall be subjected to full size testing in accordance with 6.1.3. This testing shall be in addition to tensile testing as specified in 6.1.1. The lot size shall be shown in 6.1.2.2. Failure shall occur in the body or threaded sections with no failure, or indications of failure, such as cracks, at the junction of the head and shank.

6.1.3 *Full Size Fasteners, Wedge Tensile Testing*—When applicable, see 6.1.2.3. Headed fasteners shall be wedge tested full size in accordance with Annex A3 of Test Methods and Definitions A 370 and shall conform to the tensile strength shown in Table 1. The minimum full size breaking strength (lbf) for individual sizes shall be as follows:

$$Ts = UTS \times As \tag{1}$$

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

TABLE 1 Mechanical Requirements

Class and Grade, Diameter, in [mm]	Heat Treatment	Minimum Tempering Temperature °F [°C]	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa] (0.2 % offset)	Elongation in 2 in. or 50 mm min, %	Reduction of Area, min, %	Hardness max
		Ferritic Steels					
L7, L7A, L7B, L7C, L70, L71, L72, L73			125	105	16	50	321 HB or 35 HRC
2½ [65] and under[A]	quenched and tempered	1100 [593]	[860]	[725]			
L43			125	105	16	50	321 HB or 35 HRC
4 [100] and under[A]	quenched and tempered	1100 [593]	[860]	[725]			
L7M			100	80	18	50	235 HB[B] or 99 HRB
2½ [65] and under[A]	quenched and tempered	1150 [620]	[690]	[550]			
L1 1 [25] and under[A]	quenched and tempered		125 [860]	105 [725]	16	50	. . .
		Austenitic Steels[C]					
Class 1: B8, B8C, B8M, B8P, B8F, B8T, B8LN, B8MLN, all diameters	carbide solution treated		75 [515]	30 [205]	30	50	223 HB[D] or 96 HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8FA, B8TA, B8LNA, B8MLNA, all diameters	carbide solution treated in the finished condition		75 [515]	30 [205]	30	50	192 HB or 90 HRB
Class 2: B8, B8C, B8P, B8F, B8T:	carbide solution treated and strain hardened						
¾ [20] and under			125 [860]	100 [690]	12	35	321 HB or 35 HRC
over ¾ to 1 [20 to 25], incl			115 [795]	80 [550]	15	30	321 HB or 35 HRC
over 1 to 1¼ [25 to 32], incl			105 [725]	65 [450]	20	35	321 HB or 35 HRC
over 1¼ to 1½ [32 to 40], incl[A]			100 [690]	50 [345]	28	45	321 HB or 35 HRC
Class 2: B8M:	carbide solution treated and strain hardened						
¾ [20] and under			110 [760]	95 [655]	15	45	321 HB or 35 HRC
over ¾ to 1 [20 to 25], incl			100 [690]	80 [550]	20	45	321 HB or 35 HRC
over 1 to 1¼ [25 to 32], incl			95 [655]	65 [450]	25	45	321 HB or 35 HRC
over 1¼ to 1½ [32 to 40], incl[A]			90 [620]	50 [345]	30	45	321 HB or 35 HRC

[A] These upper diameter limits were established on the basis that these were the largest sizes commonly available that consistently met specification property limits. They are not intended as absolute limits beyond which bolting materials could no longer be certified to the specification.

[B] To meet the tensile requirements, the Brinell hardness shall not be less than 200 HB or 93 HRB.

[C] Class 1 products are made from solution-treated material. Class 1A products are solution treated in the finished condition for corrosion resistance; heat treatment is critical for enhancing this physical property and meeting the mechanical property requirements. Class 2 products are made from solution-treated material that has been strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the cross section, particularly in sizes over ¾ in. [20 mm] in diameter.

[D] For sizes ¾ in. [20 mm] in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.

TABLE 2 Impact Energy Absorption Requirements

Size of Specimen, mm	Minimum Impact Value Required for Average of Each Set of Three Specimens, ft·lbf [J]	Minimum Impact Value Permitted for One Specimen Only of a Set, ft·lbf [J]
	All Grades Except L1[A]	
10 by 10	20 [27]	15 [20]
10 by 7.5	16 [22]	12 [16]
	Grade L1	
10 by 10	40 [54]	30 [41]
10 by 7.5	32 [44]	24 [32]

[A] See 6.2.1.1 for permitted exemptions.

where:
Ts = Wedge tensile strength
UTS = Tensile strength specified in Table 1, and
As = Stress area, square inches, as shown in ANSI B1.1 or calculated as follows:

$$As = 0.785 \, (D - (0.974/n))^2 \tag{2}$$

where:
D = Nominal thread size, and
n = The number of threads per inch.

6.2 *Impact Properties*:

6.2.1 *Requirements*:

6.2.1.1 Material of Grades L7, L7A, L7B, L7C, L7M, L43, L70, L71, L72, and L73 shall show a minimum impact energy absorption of 20 ft · lbf [27 J] and of Grade L1 a minimum impact energy absorption of 40 ft · lbf [54 J] at the test temperature when tested by the procedure specified in the applicable portions of Sections 19 to 28 of Test Methods and Definitions A 370. The temperature of the coolant used for chilling the test specimens shall be controlled within ±3 °F [1.5 °C]. Impact tests are not required for carbide solution treated or strain hardened Grades B8, B8F, B8P, B8M, B8T, B8LN, and B8MLN for temperatures above −325 °F [−200 °C]; for carbide solution treated Grades B8, B8P, B8C, and B8LN above −425 °F [−255 °C]; for all ferritic and austenitic steel grades of bolting ½ in. [12.5 mm] and smaller in diameter. All other material furnished under this specification shall be tested. Test temperatures for ferritic grades are listed in Table 3. Exceptions to this requirement are permissible, and the impact tests may be made at specified temperatures different than those shown in Table 3, provided the test temperature is at least as low as the intended service temperature and the bolting is suitably marked to identify the reported test temperature. When impact testing is required for austenitic grades, test criteria shall be agreed upon between the supplier and purchaser.

6.2.1.2 The impact test requirements for standard and subsize Charpy test specimens are prescribed in Table 2.

TABLE 3 Recommended Test Temperature for Stock Parts

Grade	Test Temperature °F	Test Temperature °C
L7M, L70, L71, L72, L73	−100	−73
L7, L7A, L7B, L7C	−150	−101
L43	−150	−101
L1	−100	−73

6.2.2 *Number of Tests*:

6.2.2.1 The test requirements for heat-treated bars are given in 6.1.2.1.

6.2.2.2 For test requirements on studs, bolts, screws, etc., see 6.1.2.2.

6.2.2.3 Impact tests are not required to be made on heat-treated bars, bolts, screws, studs, and stud bolts ½ in. [12.5 mm] and under in diameter.

6.2.3 *Test Specimens*—For sections 1 in. [25 mm] or less in diameter, test specimens shall be taken at the axis; for sections over 1 in. [25 mm] in diameter, midway between the axis and the surface.

6.3 *Hardness Requirements*:

6.3.1 The hardness shall conform to the requirements prescribed in Table 1. Hardness testing shall be performed in accordance with either Specification A 962/A 962M or with Test Methods F 606.

6.3.2 The maximum hardness of Grade L7M shall be 235 HB or 99 HRB (conversion in accordance with Table Number 2B of Test Methods and Definitions A 370). Minimum hardness shall not be less than 200 HB or 93 HRB. Conformance to this hardness shall be ensured by testing each bolt or stud by Brinell or Rockwell B methods in accordance with 6.3.1.

6.3.2.1 The use of 100 % electromagnetic testing for hardness as an alternative to 100 % indentation hardness testing is permissible when qualified by sampling using indentation hardness testing. Each lot tested for hardness electromagnetically shall be 100 % examined in accordance with Practice E 566. Following electromagnetic testing for hardness, a random sample of a minimum of 100 pieces in each purchase lot (as defined in 6.1.2.2) shall be tested by indentation hardness methods. All samples must meet hardness requirements to permit acceptance of the lot. If any one sample is outside of the specified maximum or minimum hardness, the lot shall be rejected and either reprocessed and resampled, or tested 100 % by indentation hardness methods.

6.3.2.2 In the event a controversy exists relative to minimum strength, tension tests shall prevail over hardness readings. Products which have been tested and found acceptable shall have a line under the grade symbol.

7. Chemical Composition

7.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 4.

8. Workmanship, Finish, and Appearance

8.1 Bolts, screws, studs, and stud bolts shall be pointed and shall have a workmanlike finish.

9. Retests

9.1 If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two additional tension tests and one additional impact test consisting of three specimens shall be made from such lot, all of which shall conform to the requirements specified.

10. Nuts and Washers

10.1 Bolts, studs, and stud bolts of Grades L7, L7A, L7B, L7C, L43, L1, L70, L71, L72, and L73 shall be equipped with ferritic alloy nuts conforming to Grade 4 or Grade 7 of Specification A 194/A 194M or a grade of steel similar to the studs. Grade 7M nuts at a hardness not exceeding 235 HB (or equivalent) shall be used with Grade L7M bolts, studs, and stud bolts. All nut materials, including those which may be supplied under Specification A 194/A 194M, shall be subject to the impact requirements of this specification in the following manner: impact tests shall be made on test specimens taken from the bar or plate from the heat of steel used for manufacturing the nuts, and heat treated with the nut blanks.

10.2 Bolts, studs, and stud bolts of Grades B8, B8C, B8T, B8P, B8F, B8M, B8LN, and B8MLN shall be equipped with austenitic alloy nuts conforming to Grades 8, 8C, 8T, 8F, 8M, 8LN, and 8MLN for Specification A 194/A 194M. Impact tests are not required for Grades 8F, 8M, 8T, and 8MLN for temperatures above −325 °F [−200 °C] and for Grades 8, 8P, 8C, and 8LN above −425 °F [−255 °C].

10.3 If the purchaser requires nuts with a Charpy impact energy absorption of not less than 20 ft · lbf [27 J] at temperatures below −150 °F [−100 °C], he may require that the nuts conform to Grades 8, 8C, 8M, 8P, 8T, 8F, 8LN, or 8MLN of Specification A 194/A 194M.

10.4 Washers for use with ferritic steel bolting shall conform to Specification F 436.

10.5 Washers for use with austenitic steel bolting shall be made of austenitic steel as agreed upon between the manufacturer and purchaser.

10.6 Washer dimensions shall be in accordance with requirements of ANSI B18.22.1, unless otherwise specified in the purchase order.

11. Threads

11.1 Where practical, all threads shall be formed after heat treatment. Class 1A, Grades B8A, B8CA, B8MA, B8PA, B8FA, B8TA, B8LNA, and B8MLNA are to be solution-treated in the finished condition.

TABLE 4 Chemical Requirements (Composition, %)[A]

Type	Ferritic Steels											
Grade	L7, L7M, L70		L7A, L71		L7B, L72		L7C, L73		L43		L1	
Description	Chromium-Molybdenum[B]		Carbon-Molybdenum (AISI 4037)		Chromium-Molybdenum (AISI 4137)		Nickel-Chromium-Molybdenum (AISI 8740)		Nickel-Chromium-Molybdenum (AISI 4340)		Low-Carbon Boron	
	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under
Carbon	0.38–0.48[C]	0.02	0.35–0.40	0.02	0.35–0.40	0.02	0.38–0.43	0.02	0.38–0.43	0.02	0.17–0.24	0.01
Manganese	0.75–1.00	0.04	0.70–0.90	0.03	0.70–0.90	0.03	0.75–1.00	0.04	0.60–0.85	0.03	0.70–1.40	0.04
Phosphorus max	0.035	0.005 over	0.035	0.005 over	0.035	0.005 over	0.035	0.005 over	0.035	0.005 over	0.035	0.005 over
Sulfur, max	0.040	0.005 over	0.040	0.005 over	0.040	0.005 over	0.040	0.005 over	0.040	0.005 over	0.050	0.005 over
Silicon	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.35	0.02	0.15–0.30	0.02
Nickel	. . .	. . .	. . .	. . .	. . .	. . .	0.40–0.70	0.03	1.65–2.00	0.05	. . .	. . .
Chromium	0.80–1.10	0.05	. . .	. . .	0.80–1.10	0.05	0.40–0.60	0.03	0.70–0.90	0.03	. . .	. . .
Molybdenum	0.15–0.25	0.02	0.20–0.30	0.02	0.15–0.25	0.02	0.20–0.30	0.02	0.20–0.30	0.02	. . .	. . .
Boron	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.001–0.003	. . .

TABLE 4 *Continued*

Type	Austenitic Steels, Classes 1, 1A, and 2[D]			
Grade	B8, B8A		B8C, B8CA	
UNS Designation.	S 30400(304)		S 34700(347)	
	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under
Carbon, max	0.08	0.01 over	0.08	0.01 over
Manganese, max	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon, max	1.00	0.05 over	1.00	0.05 over
Nickel	8.0–11.0	0.15	9.0–12.0	0.15
Chromium	18.0–20.0	0.20	17.0–19.0	0.20
Columbium + Tantalum	. . .	. . .	10 × carbon content, min. –1.10 max	0.05 under

Type.	Austenitic Steels, Classes 1, 1A, and 2[D]									
Grade	B8T, B8TA		B8P, B8PA		B8F, B8FA				B8M, B8MA	
UNS Designation	S 32100(321)		S 30500		S 30300(303)		S 30323(303Se)		S 31600(316)	
	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.15	0.01 over	0.15	0.01 over	0.08	0.01 over
Manganese, max	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.20	0.010 over	0.20	0.010 over	0.045	0.010 over
Sulfur	0.030, max	0.005 over	0.030, max	0.005 over	0.15, min	0.020	0.06, max	0.010 over	0.030, max	0.005 over
Silicon, max	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over
Nickel	9.0–12.0	0.15	10.5–13.0	0.15	8.0–10.0	0.10	8.0–10.0	0.10	10.0–14.0	0.15
Chromium	17.0–19.0	0.20	17.0–19.0	0.20	17.0–19.0	0.20	17.0–19.0	0.20	16.0–18.0	0.20
Molybdenum	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	2.00–3.00	0.10
Selenium	. . .	. . .	. . .	. . .	. . .	. . .	0.15–0.35	0.03 under	. . .	. . .
Titanium	5 × carbon content, min	0.05 under	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

Type	Austenitic Steels, Classes 1 and 1A			
Grade	B8LN, B8LNA		B8MLN, B8MLNA	
UNS Designation	S 30453		S 31653	
	Range, %	Product Variation, % Over or Under	Range, %	Product Variation, % Over or Under
Carbon, max	0.030	0.005 over	0.030	0.005 over
Manganese, max	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon, max	1.00	0.05 over	1.00	0.05 over
Nickel	8.0–10.5	0.15	10.0–14.0	0.15
Chromium	18.0–20.0	0.20	16.0–18.0	0.20
Molybdenum	. . .	. . .	2.00–3.00	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01

[A] The intentional addition of Bi, Se, Te, and Pb is not permitted except for Grade B8F, in which selenium is specified and required.

[B] Typical steel compositions used for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H.

[C] For the L7M grade, a minimum carbon content of 0.28 % is permitted provided that the required tensile properties are met in the section sizes involved; the use of AISI 4130 or 4130H is allowed.

[D] Class 1 are made from solution-treated material. Class 1A products (B8A, B8CA, B8MA, B8PA, B8FA, and B8TA) are solution-treated in the finished condition. Class 2 products are solution-treated and strain-hardened.

12. Product Marking

12.1 The identification symbol shall be as shown in Table 4. In the case of Class 2, Grades B8, B8C, B8M, B8P, B8F, and B8T strain hardened as provided in Table 1, a line shall be stamped under the grade symbol in order to distinguish it from Class 1 and Class 1A bolting which has not been strain hardened. In the case of Class 1A, the marking B8A, B8CA, B8MA, B8PA, B8FA, B8TA, B8LNA, and B8MLNA identifies the material as being in the solution-treated condition in the finished state. Grade L7M which has been 100 % evaluated in conformance with this specification shall have a line under the grade symbol to distinguish it from L7M produced to previous revisions not requiring 100 % hardness testing.

12.2 For bolting materials, including threaded bars, that are furnished bundled and tagged or boxed, the tags and boxes shall carry the grade symbol for the material identification and the manufacturer's identification mark or name.

12.3 Nuts from materials that have been impact tested shall be marked with the letter "L."

12.4 For purposes of identification marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

13. Keywords

13.1 additional elements; austenitic stainless steel; bolts—steel; chromium-molybdenum steel; fasteners—steel; markings on fittings; nickel-chromium-molybdenum alloy steel; pressure vessel service; stainless steel bolting material; starting material; steel bars—alloy; steel bolting material; steel flanges; steel valves; temperature service applications—low

SUPPLEMENTARY REQUIREMENTS

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

S1. Impact Properties

S1.1 When impact properties are desired for austenitic steel grades exempt from testing under 6.2.1, test shall be made as agreed between the manufacturer and the purchaser.

S2. Lateral Expansion

S2.1 When lateral expansion measurements for ferritic steels are required in addition to the energy absorption requirements of 6.2.1.1, the minimum value for each specimen of a set must be .015 in. [0.38 mm]. The test temperature shall be specified by the purchaser and agreed upon by the producer.

NOTE S2.1—Grades L7, L7A, L7B will generally have difficulty meeting the minimum value at −150 °F [−101 °C]. Grade L43 may be preferred.

S3. Hardness Testing of Class 2 Bolting Materials for ASME Applications

S3.1 The maximum hardness shall be Rockwell C 35 immediately under the thread roots. The hardness shall be taken on a flat area at least ⅛ in. [3 mm] across, prepared by removing threads. No more material than necessary shall be removed to prepare the flat area. Hardness determinations shall be made at the same frequency as tensile tests.

APPENDIX

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars or wire to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle, and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar, so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening.

X1.2 Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined. The minimum bar size that can be used, however, is established by the configuration of the fastener, so that the configuration can affect the strength of the fastener.

X1.3 For example, a stud of a particular alloy and size may be machined from a smaller diameter bar than a bolt of the same alloy and size because a larger diameter bar is required to accommodate the head of the bolt. The stud, therefore, is likely to be stronger than the same size bolt in a given alloy.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 320/A 320M – 07, that may impact the use of this specification. (Approved September 1, 2007)

(*1*) Added hardness requirements for "L" Grades in Table 1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 320/A 320M – 05a, that may impact the use of this specification. (Approved March 1, 2007)

(*1*) Revised 5.1.4 to clarify that stress relief must follow any cutting.
(*2*) Added new Section 7 and renumbered subsequent sections.
(*3*) Revised the last section of Table 4.

Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes[1]

This standard is issued under the fixed designation A 312/A 312M; 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*

1.1 This specification[2] covers seamless, straight-seam welded, and heavily cold worked welded austenitic stainless steel pipe intended for high-temperature and general corrosive service.

NOTE 1—When the impact test criterion for a low-temperature service would be 15 ft·lbf [20 J] energy absorption or 15 mils [0.38 mm] lateral expansion, some of the austenitic stainless steel grades covered by this specification are accepted by certain pressure vessel or piping codes without the necessity of making the actual test. For example, Grades TP304, TP304L, and TP347 are accepted by the ASME Pressure Vessel Code, Section VIII Division 1, and by the Chemical Plant and Refinery Piping Code, ANSI B31.3, for service at temperatures as low as −425 °F [−250 °C] without qualification by impact tests. Other AISI stainless steel grades are usually accepted for service temperatures as low as −325 °F [−200 °C] without impact testing. Impact testing may, under certain circumstances, be required. For example, materials with chromium or nickel content outside the AISI ranges, and for material with carbon content exceeding 0.10 %, are required to be impact tested under the rules of ASME Section VIII Division 1 when service temperatures are lower than −50 °F [−45 °C].

1.2 Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP309Cb, TP309S, TP310Cb, TP310S, TP316, TP321, TP347, and TP348, and are intended for service at temperatures where creep and stress rupture properties are important.

1.3 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements call for additional tests to be made and, when desired, it is permitted to specify in the order one or more of these supplementary requirements.

1.4 Table X1.1 lists the standardized dimensions of welded and seamless stainless steel pipe as shown in ANSI B36.19. These dimensions are also applicable to heavily cold worked pipe. Pipe having other dimensions is permitted to be ordered and furnished provided such pipe complies with all other requirements of this specification.

1.5 Grades TP321 and TP321H have lower strength requirements for pipe manufactured by the seamless process in nominal wall thicknesses greater than ⅜ in. [9.5 mm].

1.6 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:* [3]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

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

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 112 Test Methods for Determining Average Grain Size

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

[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.

Current edition approved Sept. 1, 2007. Published October 2007. Originally approved in 1948. Last previous edition approved in 2006 as A 312/A 312M – 06.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-312 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.

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

E 527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *ANSI Standards:*[4]

B1.20.1 Pipe Threads, General Purpose

B36.10 Welded and Seamless Wrought Steel Pipe

B36.19 Stainless Steel Pipe

2.3 *ASME Standard:*

ASME Boiler and Pressure Vessel Code : Section VIII[5]

2.4 *AWS Standard:*

A5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Electrodes[6]

2.5 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[7]

3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Specification A 999/A 999M and Terminology A 941 are applicable to this specification.

4. Ordering Information

4.1 Orders for material to this specification shall conform to the requirements of the current edition of Specification A 999/A 999M.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 999/A 999M unless otherwise provided herein.

5.2 *Heat Treatment*:

5.2.1 All pipe shall be furnished in the heat—treated condition in accordance with the requirements of Table 2. The heat—treatment procedure, except for "H" grades, S30815, S31272, S31254, S32654, N08367, N08904, and N08926 shall consist of heating the pipe to a minimum temperature of 1900 °F [1040 °C] and quenching in water or rapidly cooling by other means.

6. Materials and Manufacture

6.1 *Manufacture*:

6.1.1 The pipe shall be manufactured by one of the following processes:

6.1.2 *Seamless (SML) pipe* shall be made by a process that does not involve welding at any stage of production.

6.1.3 *Welded (WLD) pipe* shall be made using an automatic welding process with no addition of filler metal during the welding process.

6.1.4 *Heavily cold-worked (HCW) pipe* shall be made by applying cold working of not less than 35 % reduction in thickness of both wall and weld to a welded pipe prior to the final anneal. No filler shall be used in making the weld. Prior to cold working, the weld shall be 100 % radiographically inspected in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest revision, Paragraph UW-51.

6.1.5 Welded pipe and HCW pipe of NPS 14 and smaller shall have a single longitudinal weld. Welded pipe and HCW pipe of a size larger than NPS 14 shall have a single longitudinal weld or shall be produced by forming and welding two longitudinal sections of flat stock when approved by the purchaser. All weld tests, examinations, inspections, or treatments shall be performed on each weld seam.

6.1.6 At the option of the manufacturer, pipe shall be either hot finished or cold finished.

6.1.7 The pipe shall be free of scale and contaminating exogenous iron particles. Pickling, blasting, or surface finishing is not mandatory when pipe is bright annealed. The purchaser is permitted to require that a passivating treatment be applied to the finished pipe.

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[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[6] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, http://www.aws.org.

[7] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

TABLE 1 Chemical Requirements

Grade	UNS Designation[A]	Composition, %[B] Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Titanium	Columbium	Tantalum, max	Nitrogen[C]	Vanadium	Copper	Cerium	Boron	Aluminum
. . .	S20400	0.030	7.0-9.0	0.045	0.030	1.00	15.0-17.0	1.50-3.00	. . .	. . .	. . .	. . .	0.15-0.30	. . .	. . .	. . .	. . .	. . .
TPXM-19	S20910	0.06	4.0-6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	. . .	0.10–0.30	. . .	0.20–0.40	0.10–0.30	. . .	. . .		
TPXM-10	S21900	0.08	8.0–10.0	0.045	0.030	1.00	19.0–21.5	5.5–7.5	. . .	. . .	. . .	. . .	0.15–0.40	. . .	. . .	. . .		
TPXM-11	S21904	0.04	8.0–10.0	0.045	0.030	1.00	19.0–21.5	5.5–7.5	. . .	. . .	. . .	. . .	0.15–0.40	. . .	. . .	. . .		
TPXM-29	S24000	0.08	11.5–14.5	0.060	0.030	1.00	17.0–19.0	2.3–3.7	. . .	. . .	. . .	. . .	0.20–0.40	. . .	. . .	. . .		
TP304	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .		
TP304L	S30403	0.035[D]	2.00	0.045	0.030	1.00	18.0–20.0	8.0–13.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .		
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .		
. . .	S30415	0.04-0.06	0.80	0.045	0.030	1.00–2.00	18.0–19.0	9.0–10.0	. . .	. . .	. . .	. . .	0.12–0.18	. . .	. . .	0.03–0.08		
TP304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–18.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .		
TP304LN	S30453	0.035	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	. . .	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .		
. . .	S30600	0.018	2.00	0.02	0.02	3.7–4.3	17.0–18.5	14.0–15.5	0.20	. . .	. . .	. . .	. . .	. . .	0.50 max	. . .		
. . .	S30615	0.16–0.24	2.00	0.030	0.03	3.2-4.0	17.0–19.5	13.5–16.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.80–1.50
. . .	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	. . .	. . .	. . .	. . .	0.14–0.20	. . .	. . .	0.03–0.08		
TP309S	S30908	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	0.75	. . .	. . .	. . .	. . .	. . .		. . .		
TP309H	S30909	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .			
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	0.75	. . .	10 × C min, 1.10 max	. . .	. . .	. . .		. . .		
TP309HCb	S30941	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	0.75	. . .	10 × C min, 1.10 max	. . .	. . .	. . .				
	S31002	0.015	2.00	0.020	0.015	0.15	24.0–26.0	19.0–22.0	0.10	. . .	. . .	. . .	0.10	. . .				
TP310S	S31008	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	0.75	. . .	. . .	. . .	. . .	. . .		. . .		
TP310H	S31009	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .			
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	0.75	. . .	10 × C min, 1.10 max	. . .	. . .	. . .		. . .		
TP310HCb	S31041	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	0.75	. . .	10 × C min, 1.10 max	. . .	. . .	. . .				
. . .	S31050	0.025	2.00	0.020	0.015	0.4	24.0–26.0	20.5–23.5	1.6–2.6	. . .	. . .	. . .	0.09–0.15	. . .	. . .	. . .		
. . .	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	. . .	. . .	. . .	0.18–0.22	. . .	0.50–1.00	. . .		
	S31272	0.08–012	1.5–2.00	0.030	0.015	0.25–0.75	14.0–16.0	14.0–16.0	1.00–1.40	0.30–0.60							0.004–0.008	
	S31277	0.020	3.00	0.030	0.010	0.50	20.5–23.0	26.0–28.0	6.5–8.0				0.30–0.40		0.50–1.50			
TP316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	11.0–14.0[E]	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .		
TP316L	S31603	0.035[D]	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .		
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	16.0–18.0	11.0–14.0[E]	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .		
TP316Ti	S31635	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00-3.00	5× (C+N) –0.70	. . .	. . .	0.10	. . .	. . .	. . .	. . .	. . .
TP316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	11.0–14.0[E]	2.00–3.00				0.10–0.16	. . .	. . .	. . .		
TP316LN	S31653	0.035	2.00	0.045	0.030	1.00	16.0–18.0	11.0–14.0[E]	2.00–3.00	. . .	. . .	. . .	0.10–0.16	. . .	. . .	. . .		
TP317	S31700	0.08	2.00	0.045	0.030	1.00	18.0–20.0	11.0–14.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .		
TP317L	S31703	0.035	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .		
. . .	S31725	0.03	2.00	0.040[F]	0.030	1.00	18.0–20.0	13.5–17.5	4.0–5.0	. . .	. . .	. . .	0.10	. . .	0.75	. . .		
. . .	S31726	0.03	2.00	0.040[F]	0.030	1.00	17.0–20.0	14.5–17.5	4.0–5.0	. . .	. . .	. . .	0.10–0.20	. . .	0.75	. . .		
. . .	S31727	0.03	1.00	0.030	0.030	1.00	17.5–19.0	14.5–16.5	3.8–4.5	. . .	. . .	. . .	0.15–0.21	. . .	2.8–4.0	. . .	. . .	. . .
. . .	S32053	0.03	1.00	0.030	0.010	1.00	22.0–24.0	24.0–26.0	5.0–6.0	. . .	. . .	. . .	0.17–0.22	. . .	. . .	. . .	. . .	. . .

TABLE 1 *Continued*

Grade	UNS Designation[A]	Composition, %[B] Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Titanium	Columbium	Tantalum, max	Nitrogen[C]	Vanadium	Copper	Cerium	Boron	Aluminum
TP321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	[G]	. . .	. . .	0.10	. . .	. . .	. . .		
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	[H]	. . .	. . .	. . .	. . .	. . .	. . .		
. . .	S32615	0.07	2.00	0.045	0.030	4.8–6.0	16.5–19.5	19.0–22.0	0.30–1.50	. . .	. . .	. . .	. . .	. . .	1.50–2.50	. . .		
. . .	S32654	0.020	2.0–4.0	0.030	0.005	0.50	24.0–25.0	21.0–23.0	7.0–8.0	. . .	. . .	. . .	0.45–0.55	. . .	0.30–0.60	. . .		
. . .	S33228	0.04–0.08	1.00	0.020	0.015	0.30	26.0–28.0	31.0–33.0	. . .	. . .	0.60–1.00	. . .	. . .	. . .	. . .	0.05–0.10	. . .	0.025
. . .	S34565	0.03	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	. . .	0.10		0.40–0.60	. . .	. . .	. . .	. . .	
TP347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	. . .	. . .	[I]	. . .	. . .	. . .	. . .	. . .		
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	. . .	. . .	[J]	. . .	. . .	. . .	. . .	. . .		
TP347LN	S34751	0.005–0.020	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	. . .	. . .	0.20–0.50[F,K]	. . .	0.06–0.10	. . .	. . .	. . .	. . .	. . .
TP348	S34800	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	. . .	. . .	[I]	0.10	. . .	. . .	. . .	. . .		
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	. . .	. . .	[J]	0.10	. . .	. . .	. . .	. . .		
. . .	S35045	0.06-0.10	1.50	. . .	0.015	1.00	25.0-29.0	32.0-37.0	. . .	0.15-0.60	. . .	. . .	. . .	. . .	0.75	. . .	. . .	0.15-0.60
. . .	S35315	0.04–0.08	2.00	0.040	0.030	1.20–2.00	24.0–26.0	34.0–36.0	. . .	. . .	. . .	. . .	0.12–0.18	. . .	. . .	0.03–0.08	. . .	. . .
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.0–19.0	17.5–18.5	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .		
. . .	S38815	0.030	2.00	0.040	0.020	5.5–6.5	13.0–15.0	15.0–17.0	0.75–1.50	. . .	. . .	. . .	. . .	. . .	0.75–1.50	. . .	. . .	0.30
. . .	N08367	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	6.0–7.0	. . .	. . .	. . .	0.18–0.25	. . .	0.75	. . .	. . .	. . .
. . .	N08904	0.020	2.00	0.040	0.030	1.00	19.0–23.0	23.0–28.0	4.0–5.0	. . .	. . .	. . .	0.10	. . .	1.00–2.00	. . .	. . .	. . .
. . .	N08926	0.020	2.00	0.030	0.010	0.50	24.0–26.0	19.0–21.0	6.0–7.0	. . .	. . .	. . .	0.15–0.25	. . .	0.50–1.50	. . .	. . .	. . .

[A] New designation established in accordance with Practice E 527 and SAE J1086.
[B] Maximum, unless otherwise indicated.
[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
[D] For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.20 mm] in average wall thickness (0.044 in. [1.10 mm] in minimum wall thickness).
[E] For welded TP316, TP316N, TP316LN, and TP316H pipe, the nickel range shall be 10.0–14.0 %.
[F] For welded pipe, the phosphorus maximum shall be 0.045 %.
[G] The titanium content shall be not less than five times the carbon content and not more than 0.70 %.
[H] The titanium content shall be not less than four times the carbon content and not more than 0.60 %.
[I] The columbium content shall be not less than ten times the carbon content and not more than 1.00 %.
[J] The columbium content shall be not less than eight times the carbon content and not more than 1.0 %.
[K] Grade S34751 shall have a columbium (niobium) plus tantalum content of not less than 15 times the carbon content.

6.2 *Heat Treatment*—All pipe shall be furnished in the heat-treated condition in accordance with the requirements of Table 2. Alternatively, for seamless pipe, immediately following hot forming while the temperature of the pipes is not less than the minimum solution treatment temperature specified in Table 2, pipes shall be individually quenched in water or rapidly cooled by other means (direct quenched).

6.3 *Grain Size:*

6.3.1 The grain size of Grade UNS S32615, as determined in accordance with Test Methods E 112, shall be No. 3 or finer.

6.3.2 The grain size of grades TP309H, TP309HCb, TP310H and TP310HCb, as determined in accordance with Test Methods E 112, shall be No. 6 or coarser.

6.3.3 The grain size of grades 304H, 316H, 321H, 347H, and 348H, as determined in accordance with Test Methods E 112, shall be No. 7 or coarser.

TABLE 2 Annealing Requirements

Grade or UNS Designation[A]	Heat Treating Temperature[B]	Cooling/Testing Requirements
All grades not individually listed below:	1900 °F [1040 °C]	C
TP321H, TP347H, TP348H		
Cold finished	2000 °F [1100 °C]	D
Hot finished	1925 °F [1050 °C]	D
TP304H, TP316H		
Cold finished	1900 °F [1040 °C]	D
Hot finished	1900 °F [1040 °C]	D
TP309H, TP309HCb, TP310H, TP310HCb	1900 °F [1040 °C]	D
S30600	2010–2140 °F [1100–1170 °C]	D
S30815, S31272	1920 °F [1050 °C]	D
S31254, S32654	2100 °F [1150 °C]	D
S31277	2050 °F [1120 °C]	D
S31727, S32053	1975–2155 °F [1080–1180 °C]	D
S33228	2050–2160 °F [1120–1180 °C]	D
S34565	2050–2140 °F [1120–1170 °C]	D
S35315	2010 °F [1100 °C]	D
S38815	1950 °F [1065 °C]	D
N08367	2025 °F [1110 °C]	D
N08904	2000 °F [1100 °C]	D
N08926	2010 °F [1100 °C]	D

[A] New designation established in accordance with Practice E 527 and SAE J1086.

[B] Minimum, unless otherwise stated.

[C] Quenched in water or rapidly cooled by other means, at a rate sufficient to prevent re-precipitation of carbides, as demonstrable by the capability of pipes, heat treated by either separate solution annealing or by direct quenching, of passing Practices A 262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (see Supplementary Requirement S7). Note that Practices A 262 requires the test to be performed on sensitized specimens in the low-carbon and stabilized types and on specimens representative of the as-shipped condition for other types. In the case of low-carbon types containing 3 % or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and the purchaser.

[D] Quenched in water or rapidly cooled by other means.

7. Chemical Composition

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

8. Product Analysis

8.1 At the request of the purchaser, an analysis of one billet or one length of flat-rolled stock from each heat, or two pipes from each lot shall be made by the manufacturer. A lot of pipe shall consist of the following number of lengths of the same size and wall thickness from any one heat of steel:

NPS Designator	Lengths of Pipe in Lot
Under 2	400 or fraction thereof
2 to 5	200 or fraction thereof
6 and over	100 or fraction thereof

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 Section 7.

8.3 If the analysis of one of the tests specified in 8.1 does not conform to the requirements specified in Section 7, 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. Permitted Variations in Wall Thickness

9.1 In addition to the implicit limitation of wall thickness for seamless pipe imposed by the limitation on weight in Specification A 999/A 999M, the wall thickness for seamless and welded pipe at any point shall be within the tolerances specified in Table 3, except that for welded pipe the weld area shall not be limited by the "Over" tolerance. The wall thickness and outside diameter for inspection for compliance with this requirement for pipe ordered by NPS and schedule number is shown in Table X1.1.

10. Tensile Requirements

10.1 The tensile properties of the material shall conform to the requirements prescribed in Table 4.

11. Mechanical Tests, Grain Size Determinations, and Weld Decay Tests Required

11.1 *Mechanical Testing Lot Definition* —The term *lot* for mechanical tests shall be as follows:

11.1.1 Where the final heat treated condition is obtained, consistent with the requirements of 6.2, in a continuous furnace, by quenching after hot forming or in a batch-type furnace equipped with recording pyrometers and automatically

TABLE 3 Permitted Variations in Wall Thickness

	Tolerance, % from Nominal	
NPS Designator	Over	Under
1⁄8 to 21⁄2 incl., all t/D ratios	20.0	12.5
3 to 18 incl., t/D up to 5 % incl.	22.5	12.5
3 to 18 incl., t/D > 5 %	15.0	12.5
20 and larger, welded, all t/D ratios	17.5	12.5
20 and larger, seamless, t/D up to 5 % incl.	22.5	12.5
20 and larger, seamless, t/D > 5 %	15.0	12.5

where:
t = Nominal Wall Thickness
D = Ordered Outside Diameter

TABLE 4 Tensile Requirements

Grade	UNS Designation	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa]
. . .	S20400	95 [635]	48 [330]
TPXM-19	S20910	100 [690]	55 [380]
TPXM-10	S21900	90 [620]	50 [345]
TPXM-11	S21904	90 [620]	50 [345]
TPXM-29	S24000	100 [690]	55 [380]
TP304	S30400	75 [515]	30 [205]
TP304L	S30403	70 [485]	25 [170]
TP304H	S30409	75 [515]	30 [205]
. . .	S30415	87 [600]	42 [290]
TP304N	S30451	80 [550]	35 [240]
TP304LN	S30453	75 [515]	30 [205]
. . .	S30600	78 [540]	35 [240]
. . .	S30615	90 [620]	40 [275]
. . .	S30815	87 [600]	45 [310]
TP309S	S30908	75 [515]	30 [205]
TP309H	S30909	75 [515]	30 [205]
TP309Cb	S30940	75 [515]	30 [205]
TP309HCb	S30941	75 [515]	30 [205]
. . .	S31002	73 [500]	30 [205]
TP310S	S31008	75 [515]	30 [205]
TP310H	S31009	75 [515]	30 [205]
TP310Cb	S31040	75 [515]	30 [205]
TP310HCb	S31041	75 [515]	30 [205]
. . .	S31050:		
t ≤ 0.25 in.		84 [580]	39 [270]
t > 0.25 in.		78 [540]	37 [255]
. . .	S31254:		
t ≤ 0.187 in. [5.00 mm]		98 [675]	45 [310]
t > 0.187 in. [5.00 mm]		95 [655]	45 [310]
. . .	S31272	65 [450]	29 [200]
. . .	S31277	112 [770]	52 [360]
TP316	S31600	75 [515]	30 [205]
TP316L	S31603	70 [485]	25 [170]
TP316H	S31609	75 [515]	30 [205]
. . .	S31635	75 [515]	30 [205]
TP316N	S31651	80 [550]	35 [240]
TP316LN	S31653	75 [515]	30 [205]
TP317	S31700	75 [515]	30 [205]
TP317L	S31703	75 [515]	30 [205]
. . .	S31725	75 [515]	30 [205]
. . .	S31726	80 [550]	35 [240]
. . .	S31727	80 [550]	36 [245]
. . .	S32053	93 [640]	43 [295]
TP321	S32100:		
Welded		75 [515]	30 [205]
Seamless:			
≤ 3⁄8 in.		75 [515]	30 [205]
> 3⁄8 in.		70 [485]	25 [170]
TP321H	S32109:		
Welded		75 [515]	30 [205]
Seamless:			
≤ 3⁄16 in.		75 [515]	30 [205]
> 3⁄16 in.		70 [480]	25 [170]
. . .	S32615	80 [550]	32 [220]
. . .	S32654	109 [750]	62 [430]
. . .	S33228	73 [500]	27 [185]
. . .	S34565	115 [795]	60 [415]
TP347	S34700	75 [515]	30 [205]
TP347H	S34709	75 [515]	30 [205]
TP347LN	S34751	75 [515]	30 [205]
TP348	S34800	75 [515]	30 [205]
TP348H	S34809	75 [515]	30 [205]
. . .	S35045	70 [485]	25 [170]
. . .	S35315		
Welded		94 [650]	39 [270]
Seamless		87 [600]	38 [260]
TPXM-15	S38100	75 [515]	30 [205]
. . .	S38815	78 [540]	37 [255]
. . .	N08367:		
t ≤ 0.187		100 [690]	45 [310]
t > 0.187		95 [655]	45 [310]
. . .	N08904	71 [490]	31 [215]
. . .	N08926	94 [650]	43 [295]
Elongation in 2 in. or 50 mm (or 4*D*), min, %:		Longitudinal	Transverse
All Grades except S31050 and S32615		35	25
S32615, S31050		25	. . .
S31277		40	. . .
N08367		30	. . .

controlled within a 50 °F [30 °C] or lesser range, the term *lot* for mechanical tests shall apply to all pipes of the same specified outside diameter and specified wall thickness (or schedule) that are produced from the same heat of steel and subjected to the same finishing treatment within the same operating period.

11.1.2 Where the final heat treated condition is obtained, consistent with the requirements of 6.2, in a batch-type furnace not equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or lesser range, the term *lot* shall apply to the larger of: (a) each 200 ft [60 m] or fraction thereof and (b) those pipes heat treated in the same furnace batch charge for pipes of the same specified outside diameter and specified wall thickness (or schedule) that are produced from the same heat of steel and are subjected to the same finishing temperature within the same operating period.

11.2 *Transverse or Longitudinal Tension Test*—One tension test shall be made on a specimen for lots of not more than 100 pipes. Tension tests shall be made on specimens from two tubes for lots of more than 100 pipes.

11.3 *Flattening Test*—For material heat treated in a continuous furnace, by quenching after hot forming or in a batch-type furnace equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or lesser range, flattening tests shall be made on a sufficient number of pipe to constitute 5 % of the lot, but in no case less than 2 lengths of pipe. For material heat treated in a batch-type furnace not equipped with recording pyrometers and automatically controlled within a 50 °F [30 °C] or lesser range, flattening tests shall be made on 5 % of the pipe from each heat treated lot.

11.3.1 For welded pipe a transverse-guided face bend test of the weld may be conducted instead of a flattening test in accordance with the method outlined in the steel tubular product supplement of Test Methods and Definitions A 370. The ductility of the weld shall be considered acceptable when there is no evidence of cracks in the weld or between the weld and the base metal after bending. Test specimens from 5 % of the lot shall be taken from the pipe or test plates of the same material as the pipe, the test plates being attached to the end of the cylinder and welded as a prolongation of the pipe longitudinal seam.

11.4 *Grain Size*—Grain size determinations on Grades TP309H, TP 309HCb, TP310H, TP310HCb, and UNS S32615 shall be made on each heat treatment lot, as defined in 11.1, for the same number of pipes as prescribed for the flattening test in 11.3.

11.5 HCW pipe shall be capable of passing the weld decay tests listed in Supplementary S9 with a weld metal to base metal loss ratio of 0.90 to 1.1. The test is not required to be performed unless S9 is specified in the purchase order.

12. Hydrostatic or Nondestructive Electric Test

12.1 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.

12.2 The hydrostatic test shall be in accordance with Specification A 999/A 999M, unless specifically exempted under the provisions of 12.3.

12.3 For pipe whose dimensions equal or exceed NPS10, the purchaser, with the agreement of the manufacturer, is permitted to waive the hydrostatic test requirement when in lieu of such test the purchaser performs a system test. Each length of pipe furnished without the completed manufacturer's hydrostatic test shall include with the mandatory markings the letters "NH."

12.4 The nondestructive electric test shall be in accordance with Specification A 999/A 999M.

13. Lengths

13.1 Pipe lengths shall be in accordance with the following regular practice:

13.1.1 Unless otherwise agreed upon, all sizes from NPS ⅛ to and including NPS 8 are available in a length up to 24 ft with the permitted range of 15 to 24 ft. Short lengths are acceptable and the number and minimum length shall be agreed upon between the manufacturer and the purchaser.

13.1.2 If definite cut lengths are desired, the lengths required shall be specified in the order. No pipe shall be under the specified length and no pipe shall be more than ¼ in. [6 mm] over the specified length.

13.1.3 No jointers are permitted unless otherwise specified.

14. Workmanship, Finish, and Appearance

14.1 The finished pipes shall be reasonably straight and shall have a workmanlike finish. Removal of imperfections by grinding is permitted, provided the wall thicknesses are not decreased to less than that permitted in Section 9 of Specification A 999/A 999M.

15. Repair by Welding

15.1 For welded pipe whose diameter equals or exceeds NPS 6, and whose nominal wall thickness equals or exceeds 0.200, it is permitted to make weld repairs to the weld seam with the addition of compatible filler metal using the same procedures specified for plate defects in the section on Repair by Welding of Specification A 999/A 999M.

15.2 Weld repairs of the weld seam shall not exceed 20 % of the seam length.

15.3 Weld repairs shall be made only with the gas tungsten-arc welding process using the same classification of bare filler rod qualified to the most current AWS Specification A5.9 as the grade of stainless steel pipe being repaired and as shown in Table 5. Alternatively, subject to approval by the purchaser, weld repairs shall be made only with the gas tungsten-arc welding process using a filler metal more highly alloyed than the base metal when needed for corrosion resistance or other properties.

TABLE 5 Pipe and Filler Metal Specification

Pipe	Filler Metal		
Grade	UNS Designation	AWS A5.9 Class	UNS Designation
TP304	S30400	ER308	S30800, W30840
TP304L	S30403	ER308L	S30883, W30843
TP304N	S30451	ER308	S30880, W30840
TP304LN	S30453	ER308L	S30883, W30843
TP304H	S30409	ER308	S30880, W30840
TP309Cb	S30940	. . .	. . . . . .
TP309S	S30908	. . .	. . . . . .
TP310Cb	S31040	. . .	. . . . . .
TP310S	S31008	. . .	. . . . . .
	S31272	. . .	. . . . . .
TP316	S31600	ER316	S31680, W31640
TP316L	S31603	ER316L	S31683, W31643
TP316N	S31651	ER316	S31680, W31640
TP316LN	S31653	ER316L	S31683, W31643
TP316H	S31609	ER316H	S31680, W31640
TP321	S32100	ER321	S32180, W32140
		ER347	S34780, W34740
TP347	S34700	ER347	S34780, W34740
TP348	S34800	ER347	S34780, W34740
TPXM-19	S22100	ER209	S20980, W32240
TPXM-29	S28300	ER240	S23980, W32440
. . .	N08367	. . .	N06625
. . .	S20400	ER209	S20980, W32240
. . .	N08926	. . .	N06625

15.4 Pipes that have had weld seam repairs with filler metal shall be uniquely identified and shall be so stated and identified on the certificate of tests. When filler metal other than that listed in Table 5 is used, the filler metal shall be identified on the certificate of tests.

16. Certification

16.1 In addition to the information required by Specification A 999/A 999M, the certification shall state whether or not the material was hydrostatically tested. If the material was nondestructively tested, the certification shall so state and shall state which standard practice was followed and what reference discontinuities were used.

17. Marking

17.1 In addition to the marking specified in Specification A 999/A 999M, the marking shall include the NPS (nominal pipe size) or outside diameter and schedule number or average wall thickness, heat number, and NH when hydrotesting is not performed and ET when eddy-current testing is performed or UT when ultrasonic testing is performed. The marking shall also include the manufacturer's private identifying mark, the marking requirement of 12.3, if applicable, and whether seamless (SML), welded (WLD), or heavily cold-worked (HCW). For Grades TP304H, TP316H, TP321H, TP347H, TP348H, and S30815, the marking shall also include the heat number and heat-treatment lot identification. If specified in the purchase order, the marking for pipe larger than NPS 4 shall include the weight.

18. Government Procurement

18.1 *Scale Free Pipe for Government Procurement*:

18.1.1 When specified in the contract or order, the following requirements shall be considered in the inquiry, contract or order, for agencies of the U.S. Government where scale free pipe or tube is required. These requirements shall take precedence if there is a conflict between these requirements and the product specifications.

18.1.2 The requirements of Specification A 999/A 999M for pipe and Specification A 1016/A 1016M for tubes shall be applicable when pipe or tube is ordered to this specification.

18.1.3 Pipe and tube shall be one of the following grades as specified herein:

Grade	UNS Designation
TP304	S30400
TP304L	S30403
TP304N	S30451
TP316	S31600
TP316L	S31603
TP316N	S31651
TP317	S31700
TP317L	S31703
TP321	S32100
TP347	S34700

18.1.4 *Part Number*:

Example: ASTM A 312/A 312M Pipe 304 NPS 12 SCH 40S SMLS

Specification Number	ASTM A 312
Pipe	P
Grade	304
NPS	12
Wall	0.375
SMLS OR WELDED	SML

18.1.4.1

Specification Number	ASTM A 312
Tube	T
Grade	304
Outside Diameter	0.250
Wall	0.035
SMLS OR WELDED	WLD

18.1.5 *Ordering Information*—Orders for material under this specification shall include the following in addition to the requirements of Section 4:

18.1.5.1 Pipe or tube,

18.1.5.2 Part number,

18.1.5.3 Ultrasonic inspection, if required,

18.1.5.4 If shear wave test is to be conducted in two opposite circumferential directions,

18.1.5.5 Intergranular corrosion test, and

18.1.5.6 Level of preservation and packing required.

19. Keywords

19.1 austenitic stainless steel; seamless steel pipe; stainless steel pipe; steel pipe; welded steel pipe

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 For all pipe NPS 5 and larger in nominal size there shall be one product analysis made of a representative sample from one piece for each ten lengths or fraction thereof from each heat of steel.

S1.2 For pipe smaller than NPS 5 there shall be one product analysis made from ten lengths per heat of steel or from 10 % of the number of lengths per heat of steel, whichever number is smaller.

S1.3 Individual lengths failing to conform to the chemical requirements specified in Section 7 shall be rejected.

S2. Transverse Tension Tests

S2.1 There shall be one transverse tension test made from one end of 10 % of the lengths furnished per heat of steel. This requirement is applicable only to pipe NPS 8 and larger.

S2.2 If a specimen from any length fails to conform to the tensile properties specified that length shall be rejected.

S3. Flattening Test

S3.1 The flattening test of Specification A 999/A 999M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 999/A 999M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S4. Etching Tests

S4.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate portions of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free of injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S5. Radiographic Examination

S5.1 The entire length of weld in each double welded pipe shall be radiographically examined, using X-radiation, in accordance with Paragraph UW-51 of Section VIII Division 1 of the ASME Boiler and Pressure Vessel Code. In addition to the marking required by Section 13 each pipe shall be marked “RT” after the specification and grade. Requirements of S5 shall be required in the certification.

S6. Stabilizing Heat Treatment

S6.1 Subsequent to the solution anneal required in 6.2, Grades TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be as agreed upon between the purchaser and vendor.

S7. Intergranular Corrosion Test

S7.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

S7.1.1 Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades. The applicability of this test and the preparation of the sample for testing for grades containing greater than 3 % molybdenum shall be as agreed by the purchaser and manufacturer.

NOTE S7.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S7.2 A stabilization heat treatment in accordance with Supplementary Requirement S6 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

S8. Minimum Wall Pipe

S8.1 When specified by the purchaser, pipe shall be furnished on a minimum wall basis. The wall of such pipe shall not fall below the thickness specified. In addition to the marking required by Section 17, the pipe shall be marked S8.

S9. Weld Decay Test

S9.1 When specified in the purchase order, one sample from each lot of pipe shall be subject to testing in a boiling solution of 50 % reagent grade hydrochloric acid and 50 % water.

S9.2 The sample, of approximately 2–in. [50–mm] length, shall be prepared from a production length of pipe. Depending on the size of the pipe, it is permitted to section the sample longitudinally to allow it to fit in the Erlenmeyer flask. As a minimum, the tested sample shall include the entire weld and adjacent area and the full length of base metal 180° across from the weld. All burrs and sharp edges shall be removed by light grinding. Dust and grease shall be removed by cleaning with soap and water or other suitable solvents.

S9.3 The hydrochloric acid solution shall be prepared by slowly adding reagent grade (approximately 37 %) hydrochloric acid to an equal volume of distilled water.

Warning—Protect eyes and use rubber gloves when handling acid. Mixing and testing shall be performed in a protective enclosure.

S9.4 The test container shall be a 1–L Erlenmeyer flask equipped with ground-glass joints and an Ahline condenser. The volume of the solution shall be approximately 700 mL.

S9.5 The thickness of the weld and the base metal 180° from the weld shall be measured near both ends of the sample. These measurements shall be made with a micrometer with an anvil shape suitable for measuring the thickness with an accuracy to at least 0.001 in. [0.025 mm].

S9.6 The sample sections, both weld and base metal, shall be immersed in the flask containing the solution. Boiling chips shall be added and the solution brought to a boil. Boiling shall be maintained through the duration of the test. The time of testing shall be that which is required to remove 40 to 60 % of the original base metal thickness (usually 2 h or less) If more than 60 % of the base metal thickness remains, it is permitted to terminate the test after 24 h.

S9.7 At the end of the test period, the samples shall be removed from the solution, rinsed with distilled water, and dried.

S9.8 The thickness measurements as in S9.5 shall be repeated. The anvil shape of the micrometer used shall be suitable for measuring the minimum remaining thickness with an accuracy to at least 0.001 in. [0.025 mm].

S9.9 The corrosion ratio, R, shall be calculated as follows:

$$R = (W_0 - W) / (B_0 - B)$$

where:
W_0 = average weld-metal thickness before the test,
W = average weld-metal thickness after the test,
B_0 = average base-metal thickness before the test, and
B = average base-metal thickness after the test,

S9.9.1 The corrosion ratio for HCW pipe shall be as specified in 11.5.

S9.9.2 The corrosion ratio shall be 1.25 or less, or as further restricted in the purchase order, when the weld decay test is specified for welded (WLD) pipe.

APPENDIX

(Nonmandatory Information)

X1. DIMENSIONS OF WELDED AND SEAMLESS STAINLESS STEEL PIPE

X1.1 Table X1.1 is based on Table number 1 of the American National Standard for stainless steel pipe (ANSI B36.19).

TABLE X1.1 Dimensions of Welded and Seamless Stainless Steel Pipe

NOTE 1—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
	in.	mm	Schedule 5S[A]		Schedule 10S[A]		Schedule 40S		Schedule 80S	
			in.	mm	in.	mm	in.	mm	in.	mm
⅛	0.405	10.29	...	...	0.049	1.24	0.068	1.73	0.095	2.41
¼	0.540	13.72	...	...	0.065	1.65	0.088	2.24	0.119	3.02
⅜	0.675	17.15	...	...	0.065	1.65	0.091	2.31	0.126	3.20
½	0.840	21.34	0.065	1.65	0.083	2.11	0.109	2.77	0.147	3.73
¾	1.050	26.67	0.065	1.65	0.083	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065	1.65	0.109	2.77	0.133	3.38	0.179	4.55
1¼	1.660	42.16	0.065	1.65	0.109	2.77	0.140	3.56	0.191	4.85
1½	1.900	48.26	0.065	1.65	0.109	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065	1.65	0.109	2.77	0.154	3.91	0.218	5.54
2½	2.875	73.03	0.083	2.11	0.120	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120	3.05	0.216	5.49	0.300	7.62
3½	4.000	101.60	0.083	2.11	0.120	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109	2.77	0.134	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109	2.77	0.148	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134	3.40	0.165	4.19	0.365	9.27	0.500[B]	12.70[B]
12	12.750	323.85	0.156	3.96	0.180	4.57	0.375[B]	9.52[B]	0.500[B]	12.70[B]
14	14.000	355.60	0.156	3.96	0.188[B]	4.78[B]	...	...	...	...
16	16.000	406.40	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
18	18.000	457.20	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
20	20.000	508.00	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
22	22.000	558.80	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
24	24.000	609.60	0.218	5.54	0.250	6.35	...	...	...	...
30	30.000	762.00	0.250	6.35	0.312	7.92	...	...	...	...

[A] Schedules 5S and 10S wall thicknesses do not permit threading in accordance with the American National Standard for Pipe Threads (ANSI B1.20.1).
[B] These do not conform to the American National Standard for Welded and Seamless Wrought Steel Pipe (ANSI B36.10–1979).

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 312/A 312M-06, that may impact the use of this specification. (Approved September 1, 2007)

(*1*) Added UNS S31727 and S32053 to Table 1, Table 2, and Table 4.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 312/A 312M-05a, that may impact the use of this specification. (Approved May 1, 2006)

(*1*) Revised the tensile requirements for seamless pipe for UNS 35315 in Table 4.

Designation: A 270 – 03a

Standard Specification for Seamless and Welded Austenitic and Ferritic/Austenitic Stainless Steel Sanitary Tubing[1]

This standard is issued under the fixed designation A 270; 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*

1.1 This specification covers grades of seamless, welded, and heavily cold worked welded austenitic and ferritic/ austenitic stainless steel sanitary tubing intended for use in the dairy and food industry and having special surface finishes. Pharmaceutical quality may be requested, as a supplementary requirement.

1.2 This specification covers tubes in sizes up to and including 12 in. (304.8 mm) in outside diameter.

1.3 The values stated in inch-pound units are to be regarded as the standard.

1.4 Optional supplementary requirements are provided, and when one or more of these are desired, each shall be so stated in the order.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 923 Test Methods for Detecting Detrimental Intermetallic Phase in Wrought Duplex Austenitic/Ferritic Stainless Steels

A 967 Specification for Chemical Passivation Treatments for Stainless Steel Parts

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *ASME Standard:*

B46.1 Surface Texture (Surface Roughness, Waviness, and Lay)[3]

2.3 *ASME Boiler and Pressure Vessel Code:*

Section VIII Pressure Vessels[3]

2.4 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[4]

3. Terminology

3.1 *Definition:*

3.1.1 *roughness average, Ra, n*—arithmetic average surface roughness normally reported in microinches or microns; a measurement of surface roughness usually performed by moving a stylus in a straight line along the surface, although other methods may be used.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (austenitic steel tube),

4.1.3 Process seamless (SML), welded (WLD), or heavily cold worked (HCW),

4.1.4 Size (outside diameter and average wall thickness),

4.1.5 Length (specific or random),

4.1.6 Surface finish (Section 13),

4.1.7 Optional requirements (product analysis, see Section 9; hydrostatic or nondestructive electric test, see Section11).

4.1.8 Test report required (Certification Section of Specification A 1016/A 1016M),

4.1.9 Specification designation,

4.1.10 Special requirements, and

[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.

Current edition approved Dec. 1, 2003. Published January 2004. Originally approved in 1944. Last previous edition approved in 2003 as A 270–03.

[2] 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.

[3] Available from ASME International, Three Park Avenue, New York, NY 10016–5990.

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

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

4.2 Any supplementary requirements.

5. General Requirements

5.1 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.

6. Manufacture

6.1 The tubes shall be manufactured by one of the following processes:

6.1.1 Seamless (SML) tubes shall be made by a process that does not involve welding at any stage.

6.1.2 Welded (WLD) tubes shall be made using an automated welding process with no addition of filler metal during the welding process.

6.1.3 Heavily cold worked (HCW) tubes shall be made by applying cold working of not less than 35 % reduction of thickness of both wall and weld to a welded tube prior to the final anneal. No filler shall be used in making the weld. Prior to cold working, the weld shall be 100 % radiographically inspected in accordance with the requirements of ASME Boiler and Pressure Vessel Code Section VIII, Division 1, latest revision, Paragraph UW 51.

6.2 At the manufacturer's option, tubing may be furnished either hot finished or cold finished.

7. Heat Treatment

7.1 All material shall be furnished in the heat-treated condition. The heat treatment procedure, except for S31803, S32003, S32205, S32750, N08926 and N08367, shall consist of heating the material to a minimum temperature of 1900°F (1040°C) and quenching in water or rapid cooling by other means.

7.2 N08926 shall be heat-treated to a minimum temperature of 2010°F [1100°C] followed by quenching in water or rapidly cooling by other means. UNS N08367 should be solution annealed from 2025°F [1107°C] minimum followed by rapid quenching.

7.3 S31803 and S32205 shall be heat-treated in a temperature range of 1870°F [1020°C] to 2010°F [1100°C] followed by quenching in water or rapidly cooling by other means.

7.4 S32750 shall be heat-treated in a temperature range of 1880°F [1025°C] to 2060°F [1125°C] followed by quenching in water or rapidly cooling by other means.

7.5 S32003 shall be heat-treated in a temperature range of 1850°F (1010°C) to 2010°F (1100°C).

8. Chemical Composition

8.1 An analysis of either 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 given in Table 1.

9. Product Analysis

9.1 When requested by the purchaser, product analysis tolerance in Specification A 480/A 480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04 % or less.

9.2 If the original test for product analysis fails, retests of two additional 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 (Note 1) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat rolled stock or tubes that do not meet the requirements of the specification shall be rejected.

10. Mechanical Tests Required

10.1 *Reverse Flattening Test*—For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft (457 m) of finished tubing.

11. Hydrostatic or Nondestructive Electric Test

11.1 Each tube 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.

12. Permissible Variations in Dimensions

12.1 The following variations in dimensions shall apply:

12.1.1 For tubes with a specified wall thickness of 0.049 in. (1.24 mm) and greater, variations in outside diameter from those specified shall not exceed the amount prescribed in Table 2. For tubes with a specified wall thickness less than 0.049 in. (1.24 mm), the diameter tolerances shall be a matter for agreement by the manufacturer and the purchaser.

12.1.2 When tubing >4 in. (101.6 mm) outside diameter is ordered, additional ovality may be required for thin wall tubing. Thin wall tubing applies when the specified wall is less than 0.150 in. (3.81 mm). When thin wall tubing is ordered, the maximum and minimum outside diameter at any cross section shall deviate from the specified outside diameter by no more than twice the permissible variation in outside diameter given in Table 2; however, the mean diameter at that cross section must still be within the given permissible variation.

12.1.3 The wall thickness at any point shall not vary more than 12.5 %, from the specified wall thickness.

12.1.4 Variations in length shall meet the requirements in Table 2 except when the Pharmaceutical Quality Tubing (Supplementary Requirement S2) is specified.

13. Surface Finishes

13.1 The following surface finishes may be specified:

13.1.1 *Mill Finish*— A finish without additional polishing or operations intended to smooth the surface.

13.1.2 *Mechanically Polished Surface Finish*—The purchaser may specify one of the following finish numbers for a mechanically polished surface:

13.1.2.1 *Finish No. 80*—A ground finish produced by polishing a tube with an abrasive media impregnated with No. 80 grit.

TABLE 1 Chemical Requirements

Element	Grade	TP 304	TP 304L	. . .	TP 316	TP 316L	. . .	. . .	. . .	. . .	. . .	2003
	UNS Designation[A]	S30400	S30403	S31254	S31600	S31603	N08926	N08367	S31803	S32205	S32750	S32003
				Composition, %								
Carbon, max		0.08	0.035[B]	0.020	0.08	0.035[B]	0.020	0.030	0.030	0.030	0.030	0.030 max
Manganese, max		2.00	2.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00	1.20	2.00 max
Phosphorus, max		0.045	0.045	0.030	0.045	0.045	0.030	0.040	0.030	0.030	0.035	0.030
Sulfur, max		0.030	0.030	0.010	0.030	0.030	0.010	0.030	0.020	0.020	0.020	0.020 max
Silicon, max		1.00	1.00	0.80	1.00	1.00	0.50	1.00	1.00	1.00	0.80	1.00 max
Nickel		8.0–11.0	8.0–12.0	17.5–18.5	10.0–14.0	10.0–14.0	24.0–26.0	23.5–25.5	4.5–6.5	4.5–6.5	6.0–8.0	3.0–4.0
Chromium		18.0–20.0	18.0–20.0	19.5–20.5	16.0–18.0	16.0–18.0	19.0–21.0	20.0–22.0	21.0–23.0	22.0–23.0	24.0–26.0	19.5–22.5
Molybdenum		. . .	. . .	6.0–6.5	2.00–3.00	2.00–3.00	6.0–7.0	6.0–7.0	2.5–3.5	3.0–3.5	3.0–5.0	1.5–2.0
Nitrogen[C]		. . .	. . .	0.18–0.22	. . .	. . .	0.15–0.25	0.18–0.25	0.08–0.20	0.14–0.20	0.24–0.32	0.14–0.20
Copper		. . .	. . .	0.50–1.00	. . .	. . .	0.50–1.5	0.75 max	...	...	0.50 max	

[A] New designation established in accordance with Practice E 527 and SAE J 1086.

[B] For small diameter or thin walls or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP304L and TP316L. Small outside diameter tubes are defined as those less than 0.500 in. (12.7 mm) in outside diameter and light wall tubes as those less than 0.049 in. (1.24 mm) in average wall thickness (0.044 in. (1.12 mm) in minimum wall thickness).

[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

TABLE 2 Permissible Variations in Dimensions

Size, Outside Diameter, in. (mm)	Permissible Variations in Outside Diameter, in. (mm)		Permissible Variations in Cut Length, in. (mm)[A]	
	Over	Under	Over	Under
1.000 (25.4) and under	0.005 (0.13)	0.005 (0.13)	⅛ (3.2)	0
Over 1 (25.4) to 2 (50.8)	0.008 (0.20)	0.008 (0.20)	⅛ (3.2)	0
Over 2 (50.8) to 3 (76.2)	0.010 (0.25)	0.010 (0.25)	⅛ (3.2)	0
Over 3 (76.2) to 4 (101.6)	0.015 (0.38)	0.015 (0.38)	⅛ (3.2)	0
Over 4 (101.6) to 5 ½ (139.7), excl	0.015 (0.38)	0.015 (0.38)	3⁄16 (4.8)	0
5 ½ (139.7) to 8 (203.2), excl	0.030 (0.76)	0.030 (0.76)	3⁄16 (4.8)	0
8 (203.2) to 12 (304.8)	0.050 (1.27)	0.050 (1.27)	3⁄16 (4.8)	0

[A] The cut tolerances do not apply to Pharmaceuitical Tubing in S2 (see paragraph S2.7).

13.1.2.2 *Finish No. 120*—A ground finish produced by polishing a tube with an abrasive media impregnated with No. 120 grit.

13.1.2.3 *Finish No. 180*—A ground finish produced by polishing a tube with an abrasive media impregnated with No. 180 grit.

13.1.2.4 *Finish No. 240*—A ground finish produced by polishing a tube with an abrasive media impregnated with No. 240 grit.

13.1.2.5 Other mechanically polished finishes may be agreed upon between the purchaser and manufacturer.

13.1.3 *Electropolished Finish*—A bright reflective finish produced by electropolishing. The manufacturer may use other polishing operations prior to electropolishing.

13.1.4 *Maximum Roughness Average (Ra) Surface Finish*—The customer may specify a maximum Ra on the inside surface, outside surface, or both. The measurement of surface roughness shall be in accordance with ASME B46.1.

13.1.4.1 When no agreement is made regarding Ra measurement of longitudinally polished tube, disputes shall be resolved using measurements made in accordance with ASME B46.1.

13.2 The manufacturer shall select a manufacturing method to produce the specified finish. The operations may or may not include polishing.

13.2.1 The purchaser may specify the polishing type for either the inside surface, outside surface or both for the final desired effect.

13.2.1.1 *Longitudinally Polished Finish*— It is usually performed on the inside surface only.

13.2.1.2 *Circumferential (Rotary) Polished Finish*—This can be performed on either the inside surface, outside surface, or both.

13.2.1.3 When the surface is finished by circumferential mechanical polishing, the Ra measurement shall be measured in the longitudinal direction. Roughness measurement of a longitudinal mechanical polished surface shall be a matter of agreement between the manufacturer and the purchaser.

13.3 Acceptance criteria for minor surface imperfections shall be a matter for agreement by the manufacturer and the purchaser.

13.4 Combinations of the above finishes for internal and external surfaces may be specified. When tubes are polished on one surface only, the other surface may be the regular mill finish.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 1016/A 1016M and specified in the order, the marking shall include whether the tubing is seamless (SML), welded (WLD), or heavily cold worked (HCW), and the surface finish.

15. Packaging

15.1 Unless otherwise specified in the order, all tubing shall be protected for shipment by bundling, paper or burlap wrapping, or boxing at the discretion of the manufacturer.

16. Keywords

16.1 austenitic stainless steel; duplex stainless steel; ferritic/austenitic stainless steel; heavily cold worked tube; seamless steel tube; stainless steel tube; steel tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

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

S1. Intergranular Corrosion Test

S1.1 When specified on the order, intergranular corrosion tests shall be performed by the manufacturer on specimens representative of the as-shipped condition. Tubes shall be capable of passing corrosion tests in the as-shipped condition. Tests shall be performed in accordance with Practice E of Practices A 262 for austenitic stainless alloys (intergranular corrosion test) or Practice C of Test Methods A 923 for duplex alloys (S31803, S32205, or S32750, Intermetallic phase detection).

S2. Pharmaceutical Quality Tubing

S2.1 *Chemistry:*

S2.1.1 When S31600 and S31603 are ordered, sulfur content shall be restricted to the range of 0.005 to 0.017 %.

S2.2 *Tensile Requirements:*

S2.2.1 The material shall conform to the tensile requirements in Table S2.1.

S2.2.2 *Tensile Test*—One tension test shall be made on a specimen of lots not more than 50 tubes. Tension tests shall be made on specimens from two tubes for lots of more than 50 tubes (see Note S2.1).

S2.3 *Hardness Requirements:*

S2.3.1 The hardness shall meet the requirements in Table S2.1.

S2.3.2 Rockwell hardness tests shall be made on specimens from two tubes from each lot (see Note S2.1).

S2.4 *Manipulation Tests:*

S2.4.1 One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flange test, from each lot (see Note S2.2).

S2.4.2 One flange test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (see Note S2.2).

S2.5 *Finish:*

TABLE S2.1 Tensile and Hardness Requirements

Grade	UNS Designation	Tensile Strength min, ksi (MPa)	Yield Strength min, ksi (MPa)	Elongation in 2 in. min, %	Rockwell Hardness Number, max.
TP304	S30400	75 (515)	30 (205)	35	B90
TP304L	S30403	70 (485)	25 (170)	35	B90
TP316	S31600	75 (515)	30 (205)	35	B90
TP316L	S31603	70 (485)	25 (170)	35	B90
	S31803	90 (620)	65 (450)	25	C30.5
2205	S32205	95 (655)	70 (485)	25	C30.5
2507	S32750	116 (800)	80 (550)	15	C32
2003	S32003	90 (620)	65 (450)	25	C30

S2.5.1 Requirements for surface finish shall be stated on the purchase order.

S2.6 *Packaging:*

S2.6.1 Unless the customer specified otherwise, all tubing shall be end capped, plastic sleeved, and boxed.

S2.7 *Permissible Variations in Dimensions:*

S2.7.1 The wall thickness shall not vary from the specified wall thickness by more than 10 %.

S2.7.2 The cut length shall not vary over the specified length by more than 2 in. (50.8 mm) or less than 0 in. (0 mm).

NOTE S2.1—For tension and hardness test requirements, the term lot applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that 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 that 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, annealed in the same furnace at the same temperature, time at heat, and furnace speed.

NOTE S2.2—For flattening and flange requirements, the term lot applies to all tubes prior to cutting of the same nominal size and wall thickness that 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 that 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 S2.2.

TABLE S2.2 Number of Tubes in a Lot Heat Treated by the Continuous Process

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
Less than 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 wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

S3. Chemical Cleaning (Passivation)

S3.1 When specified on the purchase order, the tubing shall be chemically cleaned in accordance with a chemical treatment listed in Specification A 967 following the final polishing operation. When tubing is supplied in an unpolished condition, the cleaning shall be performed after the final finishing operation.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 270–03, that may impact the use of this specification. (Approved December 1, 2003).

(*1*) Added paragraph 7.5, annealing temperature range.
(*2*) Added S32003 chemistry to Table 1.
(*3*) Added Physical Requirements of S32003 in Table S2.1
(*4*) Clarified ordering requirements to include purchaser's responsibility in paragraph 4.1.
(*5*) Revised Outside Diameter tolerances in Table 2 to include all intermediate sizes.
(*6*) Removed comma after "Table 2" in 12.1.4.
(*7*) Added heavily cold worked (HCW) processing in paragraphs 1.1, 4.1.3, 6.1.3, 14.1, and 16.1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 270–02a, that may impact the use of this specification. (Approved April 10, 2003).

(*1*) Changed title.
(*2*) Updated scope.
(*3*) Added Specification A 480/A 480M and Test Methods A 923 to Referenced Documents section.
(*4*) Modified 7.1, added 7.3 and 7.4.
(*5*) Changed wording of 8.1.
(*6*) Added product check tolerances from Specification A 249.
(*7*) Added keywords.
(*8*) Added S31803, S32205, and S32750 to Table 1.
(*9*) Updated S1 and S1.1.
(*10*) Added Physical Requirements for S31803, S 32205, and S 32750 in Table S2.1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 270–02, that may impact the use of this specification. (Approved November 10, 2002).

(*1*) Modified OD tolerances to 4 inch and less to match the requirements of S2.
(*2*) Clarified wording of the thickness requirement.
(*3*) Elininated Table S2.3, as it is no longer required.
(*4*) Removed Table S2.3 from Note S2.2.

Designation: A 269 – 07a

Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service[1]

This standard is issued under the fixed designation A 269; 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*

1.1 This specification covers grades of nominal-wall-thickness, stainless steel tubing for general corrosion-resisting and low- or high-temperature service, as designated in Table 1.

1.2 The tubing sizes and thicknesses usually furnished to this specification are ¼ in. (6.4 mm) in inside diameter and larger and 0.020 in. (0.51 mm) in nominal wall-thickness and heavier.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. (3.2 mm) in inside diameter or 0.015 in. (0.38 mm) in thickness.

NOTE 1—Additional testing requirements may apply for use in ASME B31.3 applications.

1.4 Optional supplementary requirements are provided and, when one or more of these are desired, each shall be so stated in the order.

1.5 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 632 Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *ASME Piping Code:*

ASME B31.3 Process Piping[3]

2.3 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[4]

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 nominal wall thickness),

3.1.5 Length (specific or random),

3.1.6 Optional requirements (heat treatment, see Section 6; hydrostatic or nondestructive electric test, see Section 10),

3.1.7 Test report required (see Section on Inspection of Specification A 1016/A 1016M),

3.1.8 Specification designation, and

[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 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.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[4] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

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

TABLE 1 Chemical Requirements %

Grade	Composition, % TP 304	TP 304L	TP 304LN	TP 316	TP 316L	TP 316LN	TP 317	TP 321	TP 347	TP 348	TP XM-10	TP XM-11	TP XM-15	TP XM-19	TP XM-29	. . .	. . .
UNS Designation[A]	S30400	S30403	S30453	S31600	31603	S31653	S31700	S32100	S34700	S34800	S21900	S21904	S38100	S20910	S24000	S31254	S31725
Carbon	0.08 max	0.035 max[B]	0.035 max[B]	0.08 max	0.035 max[B]	0.035 max[B]	0.08 max	0.08 max	0.08 max	0.08 max	0.08 max	0.04 max	0.08 max	0.06 max	0.08 max	0.020 max	0.035 max
Manganese, max[C]	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	8.00–10.00	8.00–10.00	2.00	4.0–6.0	11.5–14.5	1.00	2.00
Phosphorus, max.	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.030	0.045	0.060	0.030	0.045
Sulfur, max.	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.015	0.030
Silicon[C]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.50–2.50	1.00	1.00	0.80	1.00
Nickel	8.0–11.0	8.0–12.0	8.0–11.0	10.0–14.0	10.0–15.0	10.0–13.0	11.0–15.0	9.0–12.0	9.0–12.0	9.0–12.0	5.5–7.5	5.5–7.5	17.5–18.5	11.5–13.5	2.3–3.7	17.5–18.5	13.5–17.5
Chromium	18.0–20.0	18.0–20.0	18.0–20.0	16.0–18.0	16.0–18.0	16.0–18.0	18.0–20.0	17.0–19.0	17.0–19.0	17.0–19.0	19.0–21.5	19.0–21.5	17.0–19.0	20.5–23.5	17.0–19.0	19.5–20.5	18.0–20.0
Molybdenum	. . .	. . .	. . .	2.00–3.00	2.00–3.00	2.00–3.00	3.0–4.0	. . .	. . .	. . .	. . .	. . .	. . .	1.50–3.00	...	6.0–6.5	4.0–5.0
Titanium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	[D]	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Columbium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	10 × C min 1.10 max	[E]	. . .	. . .	. . .	0.10–0.30	. . .	. . .	. . .
Tantalum, max	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.10	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Nitrogen[F]	. . .	. . .	0.10–0.16	. . .	. . .	0.10–0.16	. . .	. . .	. . .	. . .	0.15–0.40	0.15–0.40	. . .	0.20–0.40	0.20–0.40	0.18–0.22	0.20 max
Vanadium	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .			. . .	0.10–0.30	. . .		. . .
Copper	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.50–1.00	. . .
Others	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Co 0.20 max	. . .	. . .	. . .	. . .	. . .	. . .	. . .

TABLE 1 *Continued*

Grade	Composition, %									
	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
UNS Designation^{A}	S31726	S31727	S32053	S30600^{A}	S24565	S32654	S35045	N08367	N08926	N08904
Carbon	0.035 max	0.030 max	0.030 max	0.018 max	0.030 max	0.020 max	0.06–0.10	0.030 max	0.020 max	0.020 max
Manganese, max^{C}	2.00	1.00	1.00	2.0	5.0–7.0	2.0–4.0	1.50	2.00	2.00	2.00
Phosphorus, max.	0.045	0.030	0.030	0.020	0.030	0.030	0.045	0.040	0.030	0.040
Sulfur, max.	0.030	0.030	0.010	0.020	0.010	0.005	0.015	0.030	0.010	0.030
Silicon^{C}	1.00	1.00	1.00	3.7–4.3	1.00	0.50	1.00	1.00	0.50	1.00
Nickel	14.5–17.5	14.5–16.5	24.0–26.0	14.0–15.5	16.0–18.0	21.0–23.0	32.0–37.0	23.5–25.5	24.0–26.0	23.0–28.0
Chromium	17.0–20.0	17.5–19.0	22.0–24.0	17.0–18.5	23.0–25.0	24.0–25.0	25.0–29.0	20.0–22.0	19.0–21.0	19.0–23.0
Molybdenum	4.0–5.0	3.8–4.5	5.0–6.0	0.20 max	4.0–5.0	7.0–8.0		6.0–7.0	6.0–7.0	4.0–5.0
Titanium	. . .	. . .	. . .	. . .	. . .	. . .	0.15–0.60	. . .	. . .	. . .
Columbium	. . .	. . .	. . .	. . .	0.10 max	. . .	. . .	. . .	. . .	. . .
Tantalum, max	. . .		. . .		. . .	. . .	. . .	. . .	. . .	. . .
Nitrogen^{F}	0.10–0.20	0.15–0.21	0.17–0.22		0.40–0.60	0.45–0.55	. . .	0.18–0.25	0.15–0.25	0.10 max
Vanadium	. . .		. . .			. . .	. . .	. . .	. . .	. . .
Copper	. . .	2.8–4.0	. . .	0.50 max	. . .	0.30–0.60	0.75	0.75 max	0.50–1.50	1.00–2.00
Others	. . .	. . .	. . .	. . .	. . .	. . .	Al 0.15–0.60	. . .	. . .	. . .

^{A} New designation established in accordance with Practice E 527 and SAE J1086.

^{B} For small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in grades TP 304L, TP 304LN, 316L and 316LN. Small outside diameter tubes are defined as those with less than 0.500 in. [12.7 mm] in outside diameter and light walls are those less than 0.049 in. [1.2 mm] in minimum wall thickness.

^{C} Maximum, unless otherwise indicated.

^{D} Grade TP 321 shall have a titanium content of not less than five times the sum of the carbon and nitrogen content and not more than 0.70 %.

^{E} Grade TP 348 shall have a columbium plus tantalum content of not less than ten times the carbon content and not more than 1.10 %.

^{F} The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.

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. Manufacture

5.1 The tubes shall be made by the seamless or welded process.

5.2 At the manufacturer's option, tubing may be furnished either hot finished or cold finished.

6. Heat Treatment

6.1 All material shall be furnished in the heat-treated condition. Except as provided in 6.2, the heat-treatment procedure shall, except for S31254 and S32654 (see 6.3), S24565 (see 6.4), N08367 (see 6.8), N08904 (see 6.5) and N08926 (see 6.7), consist of heating the material to a minimum temperature of 1900 °F (1040 °C) and quenching in water or rapidly cooling by other means. Alternatively, for seamless tubes, immediately following hot forming while the temperature of the tubes is not less than the specified minimum solution treatment temperature, tubes may be individually quenched in water or rapidly cooled by other means.

6.2 Controlled structural or special service characteristics shall be specified as a guide for the most suitable heat treatment. If the final heat treatment is at a temperature under 1900 °F and is so specified on the order, each tube shall be stenciled with the final heat treatment temperature in degrees Fahrenheit after the suffix "HT".

6.3 S31254 and S32654 shall be heat-treated to a minimum temperature of 2100 °F (1150 °C) followed by quenching in water or rapidly cooling by other means.

6.4 S24565 shall be heat-treated in the range 2050 °F (1120 °C) to 2140 °F (1170 °C) followed by quenching in water or rapidly cooling by other means.

6.5 N08904 shall be heat treated to a minimum temperature of 2000 °F (1100 °C) followed by quenching in water or rapidly cooling by other means.

6.6 A solution annealing temperature above 1950 °F (1065 °C) may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP321, TP347, and TP348. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S3).

6.7 N08926 shall be heat-treated to a minimum temperature of 2010 °F (1100 °C) followed by quenching in water or rapidly cooling by other means.

6.8 UNS N08367 should be solution annealed from 2025 °F (1107 °C) minimum followed by rapid quenching.

6.9 Solution annealing of S35045 shall consist of heating the material to a temperature of 2000 °F (1093 °C) minimum for an appropriate time, followed by cooling in still air or at a faster rate.

6.10 S31727 and S32053 shall be solution annealed in the range 1975 to 2155 °F (1080 to 1180 °C) followed by quenching in water or rapidly cooling by other means.

7. Chemical Composition

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

8. Product Analysis

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

8.2 A product analysis tolerance of Table number A1.1 in Specification A 480/A 480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of .04 % or less.

8.3 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 producer, 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. Mechanical Tests Required

9.1 *Flaring Test (Seamless Tubes)*— One test shall be made on specimens from one end of one tube from each lot (Note 2) of finished tubes.

NOTE 2—The term lot applies to all tubes prior to cutting to length 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 heat-treatment 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 or when the heat-treated condition is obtained directly by quenching after hot forming, the number of tubes of the same size and from the same heat in a heat-treatment lot shall be determined from the size of the tubes as prescribed in Table 2.

9.2 *Flange Test (Welded Tubes)*—One test shall be made on specimens from one end of one tube from each lot (Note 2) of finished tubes.

9.3 *Hardness Test*—Brinell or Rockwell hardness determination shall be made on specimens from two tubes from each lot. The term *lot* applies to all tubes prior to cutting, of the same

TABLE 2 Number of Tubes in a Lot Heat Treated by the Continuous Process or by Direct Quench After Hot Forming

Size of Tube	Size of Lot
2 in. and over in outside diameter and 0.200 in. (5.08 mm) and over in wall thickness	not more than 50 tubes
Less than 2 in. but over 1 in. in outside diameter or over 1 in. in outside diameter and under 0.200 in. (5.08 mm) in wall thickness	not more than 75 tubes
1 in. or less in outside diameter	not more than 125 tubes

TABLE 3 Permissible Variations in Dimensions

Group	Size, Outside Diameter, in.	Permissible Variations in Outside Diameter, in. (mm)	Permissible Variations in Wall Thickness,[A] %	Permissible Variations in Cut Length, in. (mm)[B]		Thin Walled Tubes[C]
				Over	Under	
1	Up to ½	±0.005 (0.13)	±15	⅛ (3.2)	0	...
2	½ to 1½ , excl	±0.005 (0.13)	±10	⅛ (3.2)	0	less than 0.065 in. (1.65 mm) nominal
3	1½ to 3½ , excl	±0.010 (0.25)	±10	3⁄16 (4.8)	0	less than 0.095 in. (2.41 mm) nominal
4	3½ to 5½ , excl	±0.015 (0.38)	±10	3⁄16 (4.8)	0	less than 0.150 in. (3.81 mm) nominal
5	5½ to 8, excl	±0.030 (0.76)	±10	3⁄16 (4.8)	0	less than 0.150 in. (3.81 mm) nominal
6	8 to 12, excl	±0.040 (1.01)	±10	3⁄16 (4.8)	0	less than 0.200 in. (5.08 mm) nominal
7	12 to 14, excl	±0.050 (1.26)	±10	3⁄16 (4.8)	0	less than 0.220 in. (5.59 mm) nominal

[A] When tubes as ordered require wall thicknesses ¾ in. (19.0 mm) or over, or an inside diameter 60 % or less of the outside diameter, a wider variation in wall thickness is required. On such sizes a variation in wall thickness of 12.5 % over or under will be permitted.

For tubes less than ½ in. (12.7 mm) in inside diameter which cannot be successfully drawn over a mandrel, the wall thickness may vary ±15 % from that specified.

[B] These tolerances apply to cut lengths up to and including 24 ft (7.3 m). For lengths greater than 24 ft (7.3 m), the above over tolerances shall be increased by ⅛ in. (3 mm) for each 10 ft (3 m) or fraction thereof over 24 ft, or ½ in. (13 mm), whichever is lesser.

[C] Ovality provisions of 12.2 apply.

nominal diameter and wall thickness that 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 or when the heat-treated condition is obtained directly by quenching after hot forming, 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, or all tubes of the same size and heat, hot formed and quenched in the same production run.

9.4 When more than one heat is involved, the flaring, flanging, and hardness test requirements shall apply to each heat.

9.5 *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. Coiled tubing greater than 1500 ft (450 m) in length shall be sampled at both ends. A coil must be continuous without any circumferential butt welds.

10. Hydrostatic or Nondestructive Electric Test

10.1 Each tube 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.

11. Hardness Requirements

11.1 Grades TPXM-29, S24565, N08367, and N08926 tubes shall have a hardness number not exceeding 256 HB/270 HV or 100 HRB. Grades TPXM-10, TPXM-11, and TPXM-19 tubes shall have a hardness number not exceeding 269 HB/285 HV or 25 HRC. S31254 shall have a hardness number not exceeding 220 HB/230 HV or 96 HRB. S32654 shall have a hardness number not exceeding 250 HB/263 HV or 100 HRB. Tubes made from all other grades shall have a hardness number not exceeding 192 HB/200 HV or 90 HRB.

11.2 For tubing less than 0.065 in. (1.65 mm) in wall thickness, it is permissible to use the Rockwell superficial hardness test or the Vickers hardness test. When the Vickers test is used, the values of 11.1 will apply. The superficial hardness number for Grade TPXM-29 tubes shall not exceed 80 on the 30 T scale or 92 on the 15 T scale. The hardness number for Grades TPXM-10, TPXM-11, and TPXM-19 tubes shall not exceed 46 on the 30 N scale or 73 on the 15 N scale. The hardness number for S31254 shall not exceed 79 on the 30 T scale or 91 on the 15 T scale. Tubes made from all other grades shall not exceed 74 on the 30 T scale or 88 on the 15 T scale.

11.3 The hardness test shall not be required on tubes smaller than ¼ in. (6.4 mm) in inside diameter or tubes having a wall thickness thinner than 0.020 in. (0.51 mm) (see A2.4 of Methods and Definitions A 370). Smaller or thinner tubes should be tension tested only, in accordance with Specification A 632.

12. Permissible Variations in Dimensions

12.1 Variations in outside diameter, wall thickness, and length, from those specified, shall not exceed the amounts prescribed in Table 3.

12.2 The permissible variations in outside diameter given in Table 3 are not sufficient to provide for ovality in thin-walled tubes, as defined in the Table. In such tubes, the maximum and minimum diameters at any cross section shall deviate from the nominal diameter by no more than twice the permissible variation in outside diameter given in Table 3; however, the mean diameter at that cross section must still be within the given permissible variation.

13. Surface Condition

13.1 The tubes shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 1016/A 1016M, the marking shall include whether the tubing is seamless or welded and the final heat-treatment temperature in degrees Fahrenheit after the suffix "HT" if the final heat treatment temperature is under 1900°F (1040°C).

14.2 When the Nondestructive Electric Test is performed, each length of tubing shall be marked with the letters "NDE," and the certification, when required, shall also indicate this test.

15. Keywords

15.1 austenitic stainless steel; seamless steel tube; stainless steel tube; steel tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

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

S1. Stress-Relieved Annealed Tubes

S1.1 For use in certain corrosives, particularly chlorides where stress corrosion may occur, tubes in Grades TP304L, TP316L, TP321, TP347, and TP348 may be specified in the stress-relieved-annealed condition.

S1.2 When stress-relieved tubes are specified, tubes shall be given a heat treatment at 1550 to 1650 °F (845 to 900 °C) after roll straightening. Cooling from this temperature range may be either in air or by slow cooling. No mechanical straightening is permitted after the stress-relief treatment.

S1.3 Straightness of the tubes and additional details of this supplementary requirement shall be agreed upon between the manufacturer and purchaser.

S2. Air Underwater Pressure Test

S2.1 When specified, the tubing shall be examined by the air underwater pressure test.

S3. Stabilizing Heat Treatment

S3.1 Subsequent to the solution anneal required in Section 6, Grades TP321, TP347, and TP348 shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S4. Intergranular Corrosion Test

S4.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

S4.2 A stabilization heat treatment in accordance with Supplementary Requirement S3 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium.

NOTE S4.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 269 – 07, that may impact the use of this specification. (Approved September 1, 2007)

(*1*) Added UNS 31727 and S32053 in Table 1 and new 6.10.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 269 – 04, that may impact the use of this specification. (Approved March 1, 2007)

(*1*) Corrected Cr and Ni ranges for UNS N08904 in Table 1.

Designation: A 268/A 268M – 05a

Standard Specification for Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service[1]

This standard is issued under the fixed designation A 268/A 268M; 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*

1.1 This specification[2] covers a number of grades of nominal-wall-thickness, stainless steel tubing for general corrosion-resisting and high-temperature service. Most of these grades are commonly known as the "straight-chromium" types and are characterized by being ferromagnetic. Two of these grades, TP410 and UNS S 41500 (Table 1), are amenable to hardening by heat treatment, and the high-chromium, ferritic alloys are sensitive to notch-brittleness on slow cooling to ordinary temperatures. These features should be recognized in the use of these materials. Grade TP439 is used primarily for hot-water tank service and does not require post-weld heat treatment to prevent attack of the heat affected zone.

1.2 An optional supplementary requirement is provided, and when desired, shall be so stated in the order.

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:* [3]

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing

3. Terminology

3.1 *Lot Definitions*:

3.1.1 For flange and flaring requirements, the term lot applies to all tubes, prior to cutting, of the same nominal size and wall thickness that are produced from the same heat of steel. If 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 that are heat treated in the same furnace charge. If 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 given in Table 2.

3.1.2 For tensile and hardness test requirements, the term lot applies to all tubes, prior to cutting, of the same nominal diameter and wall thickness that are produced from the same heat of steel. If final heat treatment is in a batch-type furnace, a lot shall include only those tubes of the same size and the same heat that are heat treated in the same furnace charge. If 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.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (seamless or welded tubes),

4.1.3 Grade (Table 1),

4.1.4 Size (outside diameter and nominal wall thickness),

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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.

Current edition approved September 1, 2005. Published September 2005. Originally approved in 1944. Last previous edition approved in 2005 as A 268/A 268M – 05.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-268 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.

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

TABLE 1 Chemical Requirements

Grade	TP405	TP410	TP429	TP430	TP443	TP446–1	TP446–2[A]	. . .	TP409
UNS Designation	S40500	S41000	S42900	S43000	S44300	S44600	S44600	S40800	S40900
Element	Composition, %								
C, max	0.08	0.15	0.12	0.12	0.20	0.20	0.12	0.08	0.08
Mn, max	1.00	1.00	1.00	1.00	1.00	1.50	1.50	1.00	1.00
P, max	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.045	0.045
S, max	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.045	0.030
Si, max	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Ni	0.50 max	. . .	. . .	. . .	0.75 max	0.75 max	0.50 max	0.80 max	0.50 max
Cr	11.5–14.5	11.5–13.5	14.0–16.0	16.0–18.0	18.0–23.0	23.0–27.0	23.0–27.0	11.5–13.0	10.5–11.7
Mo	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Al	0.10–0.30	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Cu	. . .	. . .	. . .	. . .	0.90–1.25	. . .	. . .	. . .	. . .
N	. . .	. . .	. . .	. . .	. . .	0.25	0.25	. . .	. . .
Ti	. . .	. . .	. . .	. . .	. . .	. . .	. . .	12 × C min; 1.10 max	6 × C min; 0.75 max

TABLE 1 *Continued*

Grade	TP439	. . .	. . .	TP430 Ti	TP XM-27	TP XM-33[A]	18Cr-2Mo	29-4	29-4-2	26-3-3	25-4-4	...	. . .	. . .	. . .	. . .	TP468
UNS Designation	S43035	S43932	S41500[B]	S43036	S44627	S44626	S44400	S44700	S44800	S44660	S44635	S44735	S32803	S40977	S43940	S42035	S46800
Element	Composition, %																
C, max	0.07	0.030	0.05	0.10	0.01[A]	0.06	0.025	0.010	0.010	0.030	0.025	0.030	0.015[C]	0.03	0.03	0.08	0.030
Mn, max	1.00	1.00	0.5–1.0	1.00	0.40	0.75	1.00	0.30	0.30	1.00	1.00	1.00	0.5	1.50	1.00	1.00	1.00
P, max	0.040	0.040	0.03	0.040	0.02	0.040	0.040	0.025	0.025	0.040	0.040	0.040	0.020	0.040	0.040	0.045	0.040
S, max	0.030	0.030	0.03	0.030	0.02	0.020	0.030	0.020	0.020	0.030	0.030	0.030	0.005	0.015	0.015	0.030	0.030
Si, max	1.00	1.00	0.60	1.00	0.40	0.75	1.00	0.20	0.20	1.00	0.75	1.00	0.50	1.00	1.00	1.00	1.00
Ni	0.50 max	0.50	3.5–5.5	0.75 max	0.5[D] max	0.50 max	1.00 max	0.15 max	2.0–2.5	1.0–3.50	3.5–4.5	1.00 max	3.0–4.0	0.30–1.00	. . .	1.0–2.5	0.50
Cr	17.00–19.00	17.0–19.0	11.5–14.0	16.00–19.50	25.0–27.5	25.0–27.0	17.5–19.5	28.0–30.0	28.0–30.0	25.0–28.0	24.5–26.0	28.00–30.00	28.0–29.0	10.50–12.50	17.50–18.50	13.5–15.5	18.00–20.00
Mo	...	...	0.5–1.0	...	0.75–1.50	0.75–1.50	1.75–2.50	3.5–4.2	3.5–4.2	3.0–4.0	3.5–4.5	3.60–4.20	1.8–2.5	. . .	. . .	0.2–1.2	. . .
Al, max	0.15	0.15	. . .	...	...	...	...	...	...	...	...	...	. . .	. . .	. . .	. . .	. . .
Cu, max	...	...	. . .	...	0.2	0.20	...	0.15	0.15	...	...	...	. . .	. . .	. . .	. . .	. . .
N, max	0.04	0.030 (Ti + Cb) {0.20 + 4 (C + N)} min.; 0.75 max	. . .	...	0.015	0.040	0.035	0.020[E]	0.020[E]	0.040	0.035	0.045	0.020	0.030	. . .	. . .	0.030
Ti	0.20 + 4 (C + N) min; 1.10 max		. . .	5 × C min; 0.75 max	...	7 × (C + N) but no less than 0.20 min; 1.00 max	(Ti + Cb) 0.20 + 4 (C + N) min; 0.80 max	...	...	(Ti + Cb) = 0.20–1.00 and 6 × (C + N) min	(Ti + Cb) = 0.20 + 4 (C + N) min to 0.80 max	(Ti + Cb) = 0.20–1.00 and 6 × (C+ N) min	. . .	. . .	0.10–0.60	0.30–0.50	0.07–0.30
Cb	...		. . .	...	0.05–0.20	...	...	...	...	...	...	...	0.15–0.50[F]	. . .	(3 × %C + 0.30) min	. . .	0.10–0.60 (Ti + Cb) = 0.20 +4(C+N) min;0.80 max

[A] For small diameter or thin walls, or both, tubing, where many drawing passes are required, a carbon maximum of 0.015 % is necessary. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall tubes as those less than 0.049 in. [1.2 mm] in average wall thickness (0.040 in. [1 mm] in minimum wall thickness).
[B] Plate version of CA6NM.
[C] Carbon plus nitrogen = 0.30 max.
[D] Nickel plus copper.
[E] Carbon plus nitrogen = 0.025 % max.
[F] Cb/(C + N) = 12 min.

4.1.5 Length (specific or random),

4.1.6 Optional requirements (hydrostatic or nondestructive electric test, Section 16),

4.1.7 Test report required (Certification Section of Specification A 1016/A 1016M),

4.1.8 Specification designation,

4.1.9 Intergranular corrosion test, and

4.1.10 Special requirements.

TABLE 2 Number of Tubes in a Lot Heat Treated by the Continuous Process

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
Less than 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 wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

5. General Requirements

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

6. Manufacture

6.1 The tubes shall be made by the seamless or welded process with no filler metal added.

7. Heat Treatment

7.1 As a final heat treatment, tubes shall be reheated to a temperature of 1200 °F [650 °C] or higher and cooled (as appropriate for the grade) to meet the requirements of this specification.

7.2 The martensitic grade UNS S 41500 shall be reheated to a temperature of 950 °F [510 °C] or higher and cooled as appropriate to meet the requirements of this specification.

8. Chemical Composition

8.1 The steel shall conform to the chemical requirements prescribed in Table 1.

9. Product Analysis

9.1 An analysis of either one billet or one length of flatrolled stock or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

9.2 The product analysis tolerance of the Chemical Requirements Table of A 480/A 480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04 % or less.

9.3 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 producer, each billet 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.

10. Tensile Requirements

10.1 The material shall conform to the tensile properties prescribed in Tables 3 and 4.

11. Hardness Requirements

11.1 The tubes shall have a hardness number not to exceed those prescribed in Table 5.

TABLE 3 Tensile Requirements

Grade and UNS Designation	Tensile strength, min, ksi [MPa]	Yield strength, min, ksi [MPa]	Elongation[A,B] in 2 in. or 50 mm, min, %
TP405 S40500	60 [415]	30 [205]	20
. . . S40800	55 [380]	30 [205]	20
TP410 S41000	60 [415]	30 [205]	20
TP429, TP430, and TP430 Ti S429000, S 43000, and S 43036	60 [415]	35 [240]	20
TP443 S44300	70 [485]	40 [275]	20
TP446-1 S44600	70 [485]	40 [275]	18
TP446-2 S44600	65 [450]	40 [275]	20
TP409 S40900	55 [380]	25 [170]	20
TP439 S43035	60 [415]	30 [205]	20
S43932	60 [415]	30 [205]	20
. . . S41500	115 [795]	90 [620]	15
TPXM-27 S44627	65 [450]	40 [275]	20
TPXM-33 S44626	68 [470]	45 [310]	20
18Cr-2Mo S44400	60 [415]	40 [275]	20
29-4 and 29-4-2 S44700 and S44800	80 [550]	60 [415]	20
26-3-3 S44660	85 [585]	65 [450]	20
25-4-4 S44635	90 [620]	75 [515]	20
. . . S44735	75 [515]	60 [415]	18
28-2-3.5 S32803	87 [600]	72 [500]	16
S40977	65 [450]	41 [280]	18
S43940	62 [430]	36 [250]	18
S42035	80 [550]	55 [380]	16
TP468 S46800	60 [415]	30 [205]	22

[A] For tubing smaller than ½ in. [12.7 mm] in outside diameter, the elongation values given for strip specimens in Table 2 shall apply. Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in outside diameter or with walls thinner than 0.015 in. [0.4 mm].

[B] For longitudinal strip tests a deduction of 0.90 % for TP446–1 and S 44735 and 1.00 % for all other grades shall be made from the basic minimum elongation for each 1⁄32 in. [0.8 mm] decrease in wall thickness below 5⁄16 in. [8 mm]. The following table gives the computed minimum values:

TABLE 4 Minimum Elongation Values

Wall Thickness		Elongation[A] in 2 in. or 50 mm, min, %		
in.	mm	TP446–1 and S 44735	S41500	All Other Grades
5⁄16 [0.312]	8	18	15	20
9⁄32 [0.281]	7.2	17	14	19
1⁄4 [0.250]	6.4	16	14	18
7⁄32 [0.219]	5.6	15	13	17
3⁄16 [0.188]	4.8	14	12	16
5⁄32 [0.156]	4	13	11	15
1⁄8 [0.125]	3.2	13	11	14
3⁄32 [0.094]	2.4	12	10	13
1⁄16 [0.062]	1.6	11	9	12
0.062–0.035, excl	1.6–0.9	10	8	12
0.035–0.022, excl	0.9–0.6	10	8	11
0.022–0.015, incl	0.6–0.4	10	8	11

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

Note—The above table gives the computed minimum values for each 1⁄32 in. [0.8 mm] decrease in wall thickness. Where the wall thickness lies between two values shown above, the minimum elongation value shall be determined by the following equation:

Grade	Equation
TP446–1 and S 44735	E = 28.8t + 9.00 [E = 1.13t + 9.00]
S41500	E = 24t + 7.5
All other grades	E = 32t + 10.00 [E = 1.25t + 10.00]

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

TABLE 5 Hardness Requirements.

Grade	UNS Designation	Brinell Hardness, max	Rockwell Hardness, B Scale, max
TP405	S40500	207	95
. . .	S40800	207	95
TP410	S41000	207	95
TP429, TP430, and TP430 TI	S42900, S 43000, and S 43036	190	90
TP443	S44300	207	95
TP446-1 and TP446-2	S44600	207	95
TP409	S40900	207	95
TP439	S43035[A]	190	90
	S43932	190	90
. . .	S41500	295[B]	32
TPXM-33 and TPXM-27	S44626 and S44627	241	100
18CR-2Mo	S44400	217	95
29-4 and 29-4-2	S44700 and S44800	207	100
26-3-3	S44660	265	25[B]
25-4-4	S44635	270	27[B]
. . .	S44735	. . .	100
28-2-3.5	S32803	240	100
. . .	S40977	180	88
. . .	S43940	180	88
. . .	S42035	180	88

[A] Editorially corrected October 2000.
[B] Rockwell hardness, C scale.

12. Permissible Variations in Dimensions

12.1 Variations in outside diameter, wall thickness, and length from those specified shall not exceed the amounts prescribed in Table 6.

12.2 The permissible variations in outside diameter given in Table 6 are not sufficient to provide for ovality in thin-walled tubes, as defined in the Table. In such tubes, the maximum and minimum diameters at any cross section shall deviate from the nominal diameter by no more than twice the permissible variation in outside diameter given in Table 6; however, the mean diameter at that cross section must still be within the given permissible variation.

12.3 When the specified wall is 2 % or less of the specified outside diameter, the method of measurement is in accordance with the agreement between the purchaser and the manufacturer (see Note 1).

Note 1—Very thin wall tubing may not be stiff enough for the outside diameter to be accurately measured with a point contact test method, such as with the use of a micrometer or caliper. When very thin walls are specified, "go"–"no go" ring gages are commonly used to measure diameters of 1½ in. [38.1 mm] or less. A0.002-in. [0.05-mm] additional tolerance is usually added on the "go" ring gage to allow clearance for sliding. On larger diameters, measurement is commonly performed with a pi tape. Other test methods such as optical test methods may also be considered.

13. Surface Condition

13.1 All tubes shall be free of excessive mill scale, suitable for inspection. A slight amount of oxidation will not be considered as scale. Any special finish requirements shall be subject to agreement between the manufacturer and the purchaser.

14. Mechanical Tests Required

14.1 *Tension Tests*—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.

14.2 *Flaring Test (for Seamless Tubes)*— One test shall be made on specimens from one end of one tube from each lot of finished tubes. The minimum expansion of the inside diameter shall be 10 %. For tubes over 8 in. [203.2 mm] in outside diameter, or tubes with wall thickness 3⁄8 in. [9.52 mm] and over, the flattening test may be performed instead of the flaring test unless the flaring test is specified in the purchase order.

14.3 *Flange Test (for Welded Tubes)*— One test shall be made on specimens from one end of one tube from each lot of finished tubes. For tubes over 8 in. [203.2 mm] in outside diameter, or tubes with wall thickness 3⁄8 in. [9.52 mm] and over, the flattening test may be performed instead of the flange test unless the flange test is specified in the purchase order.

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

14.5 When more than one heat is involved, the tension, flaring, flanging, and hardness test requirements shall apply to each heat.

14.6 *Reverse Flattening Test*—For welded tubes, one reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

15. Intergranular Corrosion Test

15.1 If intergranular corrosion testing is specified in the purchase order, the test shall be made in accordance with

TABLE 6 Permissible Variations in Dimensions

Group	Size, Outside Diameter, in. [mm]	Permissible Variations in Outside Diameter, in. [mm]	Permissible Variations in Wall Thickness,[A] %	Permissible Variations in Cut Length, in.[B] [mm] Over	Under	Thin-Walled Tubes[C]
1	Up to ½ [12.7], excl	±0.005 [0.13]	±15	⅛ [3]	0	. . .
2	½ to 1½ [12.7 to 38.1], excl	±0.005 [0.13]	±10	⅛ [3]	0	less than 0.065 in. [1.6 mm] nominal
3	1½ to 3½ [38.1 to 88.9], excl	±0.010 [0.25]	±10	3⁄16 [5]	0	less than 0.095 in. [2.4 mm] nominal
4	3½ to 5½ [88.9 to 139.7], excl	±0.015 [0.38]	±10	3⁄16 [5]	0	less than 0.150 in. [3.8 mm] nominal
5	5½ to 8 [139.7 to 203.2], incl	±0.030 [0.76]	±10	3⁄16 [5]	0	less than 0.150 in. [3.8 mm] nominal

[A] When tubes as ordered require wall thicknesses ¾ in. [19 mm] or over, or an inside diameter 60 % or less of the outside diameter, a wider variation in wall thickness is required. On such sizes a variation in wall thickness of 12.5 % over or under will be permitted.

For tubes less than ½ in. [12.7 mm] in inside diameter which cannot be successfully drawn over a mandrel, the wall thickness may vary ±15 % from that specified.

[B] These tolerances apply to cut lengths up to and including 24 ft [7.3 m]. For lengths greater than 24 ft [7.3 m], the above over tolerances shall be increased by ⅛ in. [3 mm] for each 10 ft [3 m] or fraction thereof over 24 ft, or ½ in. [13 mm], whichever is lesser.

[C] Ovality provisions of 12.2 apply.

Practices A 763, using samples prepared as agreed upon between the seller and the purchaser.

16. Hydrostatic or Nondestructive Electric Test

16.1 Each tube, seamless or welded, 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.

17. Product Marking

17.1 In addition to the marking described in Specification A 1016/A 1016M, the marking shall indicate whether the tubing is seamless or welded.

18. Keywords

18.1 ferritic stainless steel; seamless steel tube; stainless steel tube; steel tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

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

S1. Air-Underwater Pressure Test

S1.1 When specified, the tubing shall be examined by the air underwater pressure test.

S2. Additional Testing of Welded Tubing for 100 % Joint Efficiency in Certain ASME Applications (see Note S2.1)

NOTE S2.1—When specified, the special testing in this supplement is intended for special ASME applications. It is not mandatory for all ASME applications.

S2.1 Where this supplement is specified in the purchase order, in certain ASME applications it is permissible to use 100 % joint efficiency for the longitudinal weld, provided the following additional requirements are met:

S2.1.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 1016/A 1016M.

S2.1.2 If Practice E 273 is employed, a 100 % volumetric inspection of the entire length of each tube shall also be performed using one of the non-destructive electric tests permitted by Specification A 1016/A 1016M.

S2.1.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S2.1.4 In addition to the marking prescribed in Specification A 1016/A 1016M," S2" shall be added after the grade designation.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 268/A 268M – 05, which may impact the use of this specification. (Approved September 1, 2005)

(*1*) Added S43932 to Table 1, Table 3, and Table 5.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 268/A 268M – 04a, which may impact the use of this specification. (Approved March 1, 2005)

(*1*) Clarified when ASME request applies in Supplementary Requirement S2.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 268/A 268M – 04, which may impact the use of this specification. (Approved September 1, 2004)

(*1*) Deleted references to S32900 throughout.
(*2*) Deleted references to A 789/A 789M and A 790/A 790M throughout.
(*3*) Deleted old Notes 1, 2, 3, and 4.
(*4*) Added new Section 15.
(*5*) Revised the Supplementary Requirements.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 268/A 268M – 03, which may impact the use of this specification. (Approved May 1, 2004)

(*1*) Revised grades TP 409 and TP 410 in Table 3.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 268/A 268M – 01, which may impact the use of this specification. (Approved September 10, 2003)

(*1*) Replaced Specification A 450/A 450M with Specification A 1016/A 1016M throughout.
(*2*) Clarified ordering requirements to include purchaser's responsibility in Section 4.

Standard Specification for Copper-Brazed Steel Tubing[1]

This standard is issued under the fixed designation A 254; 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

1.1 This specification covers double-wall, copper-brazed steel tubing suitable for general engineering uses, particularly in the automotive, refrigeration, and stove industries for fuel lines, brake lines, oil lines, heating and cooling units, and the like.

1.2 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[3]

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[4]

2.2 *Society of Automotive Engineers Standard:*

J 533 Flares for Tubing[5]

3. Ordering Information

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

3.1.1 Quantity (feet, metres),

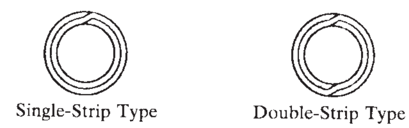
3.1.2 Name of material (copper-brazed steel tubing),

3.1.3 Type, where necessary (see Fig. 1) (normally the type is not specified),

3.1.4 Size (outside diameter and wall thickness; normally inside diameter should not be specified),

3.1.5 Length (specific or random),

3.1.6 Inside surface cleanliness where required (see Section 8),



Single-Strip Type Double-Strip Type

FIG. 1 Brazed Tubing, Double-Wall, 360-deg Brazed Construction

3.1.7 External coating, where required (see Section 7 and Supplementary Requirement S2), and

3.1.8 Special or supplementary requirements or exceptions to specification.

4. Manufacture

4.1 The steel may be made by any process.

4.2 If a specific type of melting is required by the purchaser, it shall be as stated on the purchase order.

4.3 The primary melting may incorporate separate degassing or refining and may be followed by secondary melting, such as electroslag remelting or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

4.5 The tubing shall be made by rolling steel strip into the form of tubing and subsequently copper brazing in a reducing atmosphere.

4.6 Tubing shall be constructed as shown in Fig. 1.

4.7 Tubing shall be suitably tested after brazing by the manufacturer to ensure freedom from leaks and detrimental flaws.

5. Chemical Composition

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

5.2 *Heat Analysis*—An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified. If secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Mar. 10, 1997. Published November 1997. Originally published as A 254 – 44. Last previous edition A 254 – 94.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] Discontinued 1995; see *1994 Annual Book of ASTM Standards*, Vol 03.05.

[4] Discontinued 1996; see *1995 Annual Book of ASTM Standards*, Vol 03.05. Replaced by E 1806 (Vol 03.06).

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

TABLE 1 Chemical Requirements

Element	Composition, %
Carbon	0.05 to 0.15
Manganese	0.27 to 0.63
Phosphorus, max	0.035
Sulfur, max	0.035

that determined from a product analysis made by the tubular product manufacturer shall conform to the requirements specified.

5.3 *Product Analysis*—Tubing of this quality is commonly produced in rimmed or capped steel which is characterized by a lack of uniformity in its chemical composition. For this reason, rejection for product analysis is not appropriate unless misapplication is clearly indicated.

5.4 *Methods of Analysis*—Methods described in Test Methods E 30 shall be used for referee purposes. Due allowance shall be made for the presence of copper brazing metal.

5.5 *Samples for Product Analysis*—Except for spectrographic analysis, samples shall be taken in accordance with Practice E 59.

6. Mechanical Requirements

6.1 *Tension Test*—Tensile properties of tubing as manufactured (prior to cold working) shall conform to the requirements specified in Table 2.

6.1.1 The specimens and tension tests required shall be made in accordance with Test Methods and Definitions A 370.

6.1.2 Specimens shall be tested at room temperature.

6.1.3 Test specimens shall be taken from the ends of finished tubes prior to upsetting, swaging, expanding, or other forming operations, or being cut to length. They shall be smooth on the ends and free from burrs and flaws.

6.1.4 If any test specimen shows flaws or defective machining, it may be discarded and another specimen substituted.

6.1.5 The yield strength shall be determined as that corresponding to a permanent offset of 0.2 % of the gage length of the specimen, or a total extension of 0.5 % of the gage length under load.

6.1.6 If the percentage of elongation of any test specimen is less than that specified and any part of the fracture is more than ¾ in. (19.0 mm) from the center of the gage length, as indicated by scribe marks on the specimen before testing, a retest shall be allowed.

6.2 *Flattening Test*—A section of tubing, not less than 2½ in. (64 mm) in length, shall stand being flattened between parallel plates until the inside walls are in contact without cracking or otherwise showing flaws.

6.3 *Expansion Test*—A section of tubing approximately 4 in. (100 mm) in length shall stand being expanded over a tapered mandrel having a slope of 1 in 10 until the outside diameter at the expanded end is increased 20 % without cracking or otherwise showing flaws. (Prior to the expansion test, tubing shall be cut off square, edge crowned, and deburred. It shall be held firmly and squarely in the die, and punch must be guided on the axis of the tubing.)

TABLE 2 Tensile Requirements

Property	Requirement
Tensile strength, min, psi (MPa)	42 000 (290)
Yield strength, min, psi (MPa)	25 000 (172)
Elongation in 2 in. (50.8 mm) min, %	25

6.4 *Bend Test*—The finished tubing shall stand bending on a centerline radius equal to three times the tubing outside diameter without kinking, cracking, or developing other flaws where proper bending fixtures are used.

6.5 *Pressure Proof Tests*—Each tube shall be capable of withstanding, without bursting or leaking, either of the following proof tests:

6.5.1 An internal hydrostatic pressure sufficient to subject the material to a minimum fiber stress of 16 000 psi (110 MPa). Hydrostatic pressure shall be determined by the following formula:

$$P = 2St/D$$

where:

P = hydrostatic pressure, psi (or MPa),
S = allowable fiber stress, 16 000 psi (110 MPa),
t = actual wall thickness of tubing, in. (or mm), and
D = actual outside diameter of tubing, in. (or mm).

6.5.2 An underwater air pressure between 225 and 250 psi (1.55 and 1.73 MPa).

7. Coating

7.1 Tubing may be furnished with a copper coating on the inside and outside surfaces, at the option of the manufacturer.

8. Inside Surface Cleanliness

8.1 When inside surface cleanliness is specified by the purchaser, tubing for certain uses, such as refrigeration condensers, shall conform to the following requirement for internal cleanliness:

8.1.1 When a length of tubing is washed internally with redistilled chloroform or redistilled 1,1,1-trichloroethane, the residue remaining upon evaporation of the solvent shall not exceed 1.25×10^{-4} g/in.^{2}(0.194 g/m^2) of internal surface. To perform the test, pour 100 mL of solvent through the tubing and collect. The total length of tubing tested should not be less than 40 ft (12 m), although this total length may be obtained by washing several separate lengths and pouring the same solvent through each in succession. Evaporate the solvent in a steam or hot water bath, and dry at 110°C (230°F) until the vapors are completely removed.

8.2 To maintain this level of cleanliness in shipping, handling, and storage, the purchaser may request that the manufacturer seal the tube ends with caps or closures.

9. Dimensional Tolerances

9.1 The tubing shall conform to the permissible variations in Table 3, Table 4, and Table 5.

10. Workmanship, Finish, and Appearance

10.1 Finished tubing shall be clean, smooth and round, both inside and outside, and shall be free of rust, scale, and defects that impair processing and serviceability. Finished tubes shall be reasonably straight.

TABLE 3 Outside Diameter Requirements

Specified Outside Diameter, in. (mm)	Variations, in. (mm)
	Plus or Minus
Under 3⁄16 (4.76)	0.002 (0.051)
3⁄16 (4.76) through 3⁄8 (9.53)	0.003 (0.076)
7⁄16 (11.1) through 5⁄8 (15.9)	0.004 (0.102)

TABLE 4 Wall Thickness Requirements

Specified Wall Thickness, in. (mm)	Variations, in. (mm)
	Plus or Minus
0.020 (0.51) through 0.030 (0.76)	0.003 (0.08)
0.031 (0.79) through 0.049 (1.24)	0.0035 (0.09)

TABLE 5 Length Requirements

Specified Cut Length, in. (m)	Variations, in. (mm)
18 (0.46) and under	±0.03 (±0.76)
Over 18 (0.46) through 40 (1.02)	±0.06 (±1.52)
Over 40 (1.02) through 80 (2.03)	±0.12 (±3.05)
Over 80 (2.03) through 120 (3.05)	±0.25 (±6.35)
Over 120 (3.05)	+1.00 (+25.4), −0.0

11. Retests

11.1 If the results of the mechanical tests of any group or lot do not conform to the requirements specified in the individual specification, retests may be made on additional tubes of double the original number from the same group or lot, each of which shall conform to the requirements specified.

12. Retreatment

12.1 If the individual tubes or the tubes selected to represent any group or lot fail to conform to the test requirements, the individual tubes or the group or lot represented may be retreated and resubmitted for test. Not more than two reheat treatments shall be permitted.

13. Inspection

13.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All required tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

14. Rejection

14.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the tubing may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

14.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside, and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such material shall be a matter for agreement.

15. Certification

15.1 When requested on the purchaser's order, a test report, signed by an authorized employee or representative of the manufacturer, shall be furnished to the purchaser to indicate the specification and year date and grade, the results of the chemical analysis, hardness, and tension tests, when specified, and other tests as may be specified in writing by the purchaser.

16. Product Marking

16.1 The specification number (the marking need not include the year date of the specification), the name or brand of the manufacturer and the size of tubing or the part number shall be marked on a tag or label securely attached to the bundles or boxes in which the tubes are shipped.

16.2 *Bar Coding*—In addition to the requirements in 16.1 bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

17. Keywords

17.1 steel tube

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon by the manufacturer and the purchaser.

S1. Flare Test

S1.1 Brazed tubing shall stand being double flared to dimensions shown in SAE Standard J 533, without splitting through the wall at the major diameter of the flare. A separation of the outer lap joint is permissible on the flared end of the tube only in Area *A* (see Fig. S1.1). This separation shall not exceed

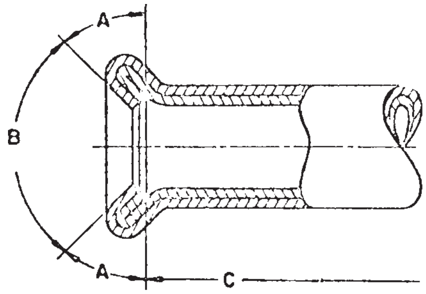


FIG. S1.1 Double-Flare Test

0.12 in. (3.0 mm) in length and shall be confined to the outer thickness only. Seam separation is not permitted in the following areas:

S1.1.1 Area *B* (the flare seat, defined as the surface within the 90° included angle); conical surface shall be smooth and free from cracks or other irregularities that could cause leaks after assembly.

S1.1.2 Area *C* (the surface beyond the length of the double thickness created by the flare).

S1.2 The flare seat may contain superficial random radial marks or indentations which are not detrimental to the sealability of the flare. No indentations of a repetitive nature resulting from flaring tooling deterioration or adhesion of chips or dirt to the flaring tooling are permissible. In the event that the physical appearance of the flare seat is questioned, the criterion for final judgment is whether or not the flare seat will seal when subjected to a pressure test at the prescribed torque level.

S2. External Coating

S2.1 The outside surface of the tubing shall be coated with a hot-dipped, lead-tin alloy coating. Weight and composition of coating shall be agreed upon between the manufacturer and purchaser.

S3. End Finish

S3.1 Finished tubing shall have smooth ends free of burrs.

Designation: A 252 – 98 (Reapproved 2002)

Standard Specification for Welded and Seamless Steel Pipe Piles[1]

This standard is issued under the fixed designation A 252; 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

1.1 This specification covers nominal (average) wall steel pipe piles of cylindrical shape and applies to pipe piles in which the steel cylinder acts as a permanent load-carrying member, or as a shell to form cast-in-place concrete piles.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions of the values in inch-pound units to values in SI units.

1.3 The text of this specification contains notes and footnotes that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

1.4 The following precautionary caveat pertains only to the test method portion, Section 16 of this specification. *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[2]

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

[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 A01.09 on Carbon Steel Tubular Products.

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[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

3. Terminology

3.1 *Definitions*—Definitions of terms used in this specification shall be in accordance with Terminology A 941.

3.1.1 *defect*—an imperfection of sufficient size or magnitude to be cause for rejection.

3.1.2 *imperfection*—any discontinuity or irregularity found in the pipe.

4. Ordering Information

4.1 Orders for material under this specification shall contain information concerning as many of the following items as are required to describe the desired material adequately:

4.1.1 Quantity (feet or number of lengths),

4.1.2 Name of material (steel pipe piles),

4.1.3 Method of manufacture (seamless or welded),

4.1.4 Grade (Tables 1 and 2),

4.1.5 Size (outside diameter and nominal wall thickness),

4.1.6 Lengths (single random, double random, or uniform) (see Section 13),

4.1.7 End finish (Section 15), and

4.1.8 ASTM specification designation and year of issue,

4.1.9 Location of purchaser's inspection (see 19.1), and

4.1.10 Bar coding (see 22.2).

5. Materials and Manufacture

5.1 The piles shall be made by the seamless, electric resistance welded, flash welded, or fusion welded process. The seams of welded pipe piles shall be longitudinal, helical-butt, or helical-lap.

NOTE 1—For welded pipe piles, the weld should not fail when the product is properly fabricated and installed and subjected to its intended end use.

6. Process

6.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

7. Chemical Composition

7.1 The steel shall contain no more than 0.050 % phosphorous.

TABLE 1 Tensile Requirements

NOTE—Where an ellipsis (...) appears in this table, there is no requirement.

	Grade 1	Grade 2	Grade 3
Tensile strength, min, psi (MPa)	50 000 (345)	60 000 (415)	66 000 (455)
Yield point or yield strength, min, psi (MPa)	30 000 (205)	35 000 (240)	45 000 (310)
Basic minimum elongation for nominal wall thicknesses 5⁄16 in. (7.9 mm) or more:			
Elongation in 8 in. (203.2 mm), min, %	18	14	. . .
Elongation in 2 in. (50.8 mm), min, %	30	25	20
For nominal wall thicknesses less than 5⁄16 in. (7.9 mm), the deduction from the basic minimum elongation in 2 in. (50.08 mm) for each 1⁄32 - in. (0.8 mm) decrease in nominal wall thickness below 5⁄16 in. (7.9 mm), in percentage points	1.50[A]	1.25[A]	1.0[A]

[A] Table 2 gives the computed minimum values:

TABLE 2 Calculated Minimum Elongation Values[A]

Nominal Wall Thickness		Elongation in 2 in. (50.8 mm), min, %		
in.	mm	Grade 1	Grade 2	Grade 3
5⁄16 or 0.312	7.9	30.00	25.00	20.00
9⁄32 or 0.281	7.1	28.50	23.75	19.00
1⁄4 or 0.250	6.4	27.00	22.50	18.00
7⁄32 or 0.219	5.6	25.50	21.25	17.00
3⁄16 or 0.188	4.8	24.00	20.00	16.00
11⁄64 or 0.172	4.4	23.25	19.50	15.50
5⁄32 or 0.156	4.0	22.50	18.75	15.00
9⁄64 or 0.141	3.6	21.75	18.25	14.50
1⁄8 or 0.125	3.2	21.00	17.50	14.00
7⁄64 or 0.109	2.8	20.25	16.75	13.50

[A] The above table gives the calculated minimum elongation values for various nominal wall thicknesses. Where the specified nominal wall thickness is intermediate to those shown above, the minimum elongation value shall be determined as follows:

Grade	
1	$E = 48t + 15.00$
2	$E = 40t + 12.50$
3	$E = 32t + 10.00$

where:
E = elongation in 2 in., %, and
t = specified nominal wall thickness, in.

8. Heat Analysis

8.1 Each heat analysis shall conform to the requirement specified in 7.1. When requested by the purchaser, the applicable heat analyses shall be reported to the purchaser ro the purchaser's representative.

9. Product Analysis

9.1 Chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

9.2 It shall be permissible for the purchaser to make product analyses using samples from lots of pipe piles as follows:

Pipe Size Outside Diameter, in. (mm)	Number of Samples and Size of Lot
Under 14 (355.6)	2 from 200 pipe or fraction thereof
14 to 36, incl (355.6 to 914)	2 from 100 pipe or fraction thereof
Over 36 (914)	2 from 3000 ft (914 m) or fraction thereof

The product analyses shall conform to the requirement in 7.1.

9.3 If the chemical compositions of both of the samples representing a lot fail to conform to the specified requirement, the lot shall be rejected or analyses of four additional samples selected from the lot shall be made, and each shall conform to the specified requirement. If the chemical composition of only one of the samples representing a lot fails to conform to the specified requirement, the lot shall be rejected or analyses of two additional samples selected from the lot shall be made, and each shall conform to the specified requirement.

10. *Tensile Requirements* Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties prescribed in Tables 1 and 2.

10.2 The yield point shall be determined by the drop of the beam, by the halt in the gage of the testing machine, by the use of dividers, or by other approved methods. When a definite yield point is not exhibited, the yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen, or to a total extension of 0.5 % of the gage length under load shall be determined.

11. Weights Per Unit Length

11.1 The weights per unit length for various sizes of pipe piles are listed in Table 3.

11.2 For pipe pile sizes not listed in Table 3, the weight per unit length shall be calculated as follows:

$$W = 10.69(D - t)t \quad (1)$$

where:

W = weight per unit length, lb/ft,
D = specified outside diameter, in., and
t = specified nominal wall thickness, in.

12. Permissible Variations in Weights and Dimensions

12.1 *Weight*—Each length of pipe pile shall be weighed separately and its weight shall not vary more than 15 % over or 5 % under its theoretical weight, calculated using its length and its weight per unit length (see Section 11).

12.2 *Outside Diameter*—The outside diameter of pipe piles shall not vary more than ±1 % from the specified outside diameter.

12.3 *Wall Thickness*—The wall thickness at any point shall not be more than 12.5 % under the specified nominal wall thickness.

NOTE 2—The minimum permissible wall thickness on inspection is shown in Table X1.1 (see Appendix) for various nominal wall thicknesses.

13. Lengths

13.1 Pipe piles shall be furnished in single random lengths, double random lengths, or in uniform lengths as specified in the purchase order, in accordance with the following limits:

Single random lengths	16 to 25 ft (4.88 to 7.62 mm), incl
Double random lengths	over 25 ft (7.62 m) with a minimum average of 35 ft (10.67 m)
Uniform lengths	length as specified with a permissible variation of ±1 in.

13.2 Lengths that have been spliced at the mill by welding shall be acceptable as the equivalent of unspliced lengths provided tension test specimens cut from sample splices conform to the tensile strength requirements prescribed in Tables 1 and 2. The welding bead shall not be removed for this test. Such specimens shall be made in accordance with the provisions specified in Sections 16-18.

TABLE 3 Common Sizes and Weights Per Unit Length[A]

Outside Diameter, in.	Nominal Wall Thickness, in.[B]	Weight per Unit Lengths, lb/ft[C]	Outside Diameter, in.[B]	Nominal Wall Thickness, in.[B]	Weight per Unit Lengths, lb/ft[C]
6	0.134	8.40	12	0.134	17.00
	0.141	8.83		0.141	17.87
	0.156	9.75		0.150	19.00
	0.164	10.23		0.164	20.75
	0.172	10.72		0.172	21.75
				0.179	22.62
8	0.141	11.85		0.188	23.74
	0.172	14.39		0.203	25.60
				0.219	27.58
8⅝	0.109	9.92		0.230	28.94
	0.141	12.79		0.250	31.40
	0.172	15.54		0.281	35.20
	0.188	16.96		0.312	38.98
	0.203	18.28			
	0.219	19.68	12¾	0.109	14.73
	0.250	22.38		0.134	18.07
	0.277	24.72		0.141	19.01
	0.312	27.73		0.150	20.20
	0.322	28.58		0.164	22.07
	0.344	30.45		0.172	23.13
	0.375	33.07		0.179	24.05
	0.438	38.33		0.188	25.25
	0.500	43.43		0.203	27.23
				0.219	29.34
10	0.109	11.53		0.230	30.78
	0.120	12.67		0.250	33.41
	0.134	14.13		0.281	37.46
	0.141	14.86		0.312	41.48
	0.150	15.79		0.330	43.81
	0.164	17.24		0.344	45.62
	0.172	18.07		0.375	49.61
	0.179	18.79		0.438	57.65
	0.188	19.72		0.500	65.48
	0.203	21.26			
	0.219	22.90	14	0.134	19.86
	0.230	24.02		0.141	20.89
	0.250	26.06		0.150	22.21
				0.164	24.26
10¾	0.109	12.40		0.172	25.43
	0.120	13.64		0.179	26.45
	0.134	15.21		0.188	27.76
	0.141	15.99		0.203	29.94
	0.150	17.00		0.219	32.26
	0.164	18.56		0.230	33.86
	0.172	19.45		0.250	36.75
	0.179	20.23		0.281	41.21
	0.188	21.23		0.312	45.65
	0.203	22.89		0.344	50.22
	0.219	24.65		0.375	54.62

TABLE 3 *Continued*

Outside Diameter, in.	Nominal Wall Thickness, in.[B]	Weight per Unit Lengths, lb/ft[C]	Outside Diameter, in.[B]	Nominal Wall Thickness, in.[B]	Weight per Unit Lengths, lb/ft[C]
	0.230	25.87		0.438	63.50
	0.250	28.06		0.469	67.84
	0.279	31.23		0.500	72.16
	0.307	34.27			
	0.344	38.27	16	0.134	22.73
	0.141	23.90			
	0.150	25.42			
	0.164	27.76			
16	0.172	29.10	20	0.188	31.78
	0.179	30.27		0.219	46.31
				0.250	52.78
	0.188	30.61		0.281	59.23
	0.203	34.28		0.312	65.66
	0.219	36.95		0.344	72.28
	0.230	38.77		0.375	78.67
	0.250	42.09		0.438	91.59
	0.281	47.22		0.469	97.92
	0.312	52.32		0.500	104.23
	0.344	57.57			
	0.375	62.64	22	0.172	40.13
	0.438	72.86		0.188	43.84
	0.469	77.87		0.219	50.99
	0.500	82.85		0.250	58.13
				0.281	65.24
18	0.141	26.92		0.312	72.34
	0.172	32.78		0.375	86.69
	0.188	35.80		0.438	100.96
	0.219	41.63		0.469	107.95
	0.230	43.69		0.500	114.92
	0.250	47.44			
	0.281	53.23	24	0.172	43.81
	0.312	58.99		0.188	47.86
	0.344	64.93		0.219	55.67
	0.375	70.65		0.250	63.47
	0.438	82.23		0.281	71.25
	0.469	87.89		0.312	79.01
	0.500	93.54		0.375	94.71
				0.438	110.32
20	0.141	29.93		0.469	117.98
	0.172	36.46		0.500	125.62

[A] Subject to agreement between the manufacturer and the purchaser, sizes and weights per unit length other than those listed shall be permitted.

[B] 1 in. = 25.4 mm

[C] 1 lb/ft = 1.49 kg/m.

14. Workmanship, Finish, and Appearance

14.1 The finished pipe piles shall be reasonably straight and shall not contain imperfections in such number or of such character as to render the pipe unsuitable for pipe piles.

14.2 Surface imperfections having a depth not in excess of 25 % of the specified nominal wall thickness shall be acceptable. It shall be permissible to establish the depth of such imperfections by grinding or filing.

14.3 Surface imperfections having a depth in excess of 25 % of the specified nominal wall thickness shall be considered to be defects. It shall be permissible for defects not deeper than 33⅓ % of the specified nominal wall thickness to be repaired by welding, provided that the defect is completely removed prior to welding.

15. Ends

15.1 Pipe piles shall be furnished with plain ends. Unless otherwise specified, pipe piles shall have either flame–cut or machine–cut ends, with the burrs at the ends removed. Where ends are specified to be beveled, they shall be beveled to an angle of 30 +5, −0°, measured from a line drawn perpendicular to the axis of the pipe pile.

16. Number of Tests

16.1 One tension test shall be made on one length or fraction thereof of each size, or one piece of skelp representing each lot of 200 lengths or fraction thereof of each size.

16.2 A retest shall be allowed if the percentage of elongation of any test tension specimen is less than that prescribed in Tables 1 and 2 and any part of the fracture is more than ¾ in. (19 mm) from the center of the gage length for test specimens having a 2–in. (50 mm) gage length, or is outside of the middle third of the gage length for test specimens having an 8–in. (200 mm) gage length, as indicated by scribe scratches marked on the specimen before testing. A retest shall also be allowed if any part of the fracture is in an inside or outside surface imperfection.

16.3 It shall be permissible to discard any test specimen that shows defective machining or develops imperfections and substitute another test specimen.

17. Retests

17.1 If the results of the tension test representing any lot fail to conform to the applicable requirements prescribed in Tables 1 and 2, the lot shall be rejected or retested using two additional lengths from the lot, with each such test being required to conform to such specified requirements.

18. Test Specimens and Test Methods

18.1 The tension test specimens and test methods shall be in accordance with Test Methods and Definitions A 370, especially Annex A2.

18.2 At the option of the manufacturer, the tension test specimens shall be longitudinal or transverse strip test specimens, with a gage length of 2 in. (50 mm) or 8 in. (200 mm), taken from the pipe or the skelp. Within their gage length, longitudinal strip test specimens shall be nominally 1½ in. (38 mm) wide, non-flattened, and with parallel sides.

18.3 For welded pipe piles, the tension test specimens shall be taken as follows:

18.3.1 For longitudinal–seam pipe piles, any longitudinal strip test specimens shall be taken from the pipe parallel to the pipe axis and 90° from the weld, or from the skelp at a corresponding location and orientation, and any transverse strip test specimens shall be taken from the pipe 90° to the pipe axis and 180° from the weld, or from the skelp at a corresponding location and orientation.

18.3.2 For helical-seam pipe piles, any longitudinal strip test specimens shall be taken from the pipe parallel to the pipe axis and at such a location that the center of the specimen is located at least a quarter of the distance between adjacent weld convolutions, or from the skelp at a corresponding location and orientation; and transverse specimens shall be taken from the pipe 90° to the pipe axis and at such a location that the center of the specimen is located approximately half the distance between adjacent weld convolutions, or from the skelp at a corresponding location and orientation.

18.4 Specimens shall be tested at room temperature.

19. Inspection

19.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with the requirements of this specification and any other requirements specified in the purchase order. All tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise specified in the purchase order, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

20. Rejection

20.1 It shall be permissible for the purchaser inspect the pipe piles received from the manufacturer and reject any pipe pile that does not meet the requirements of this specification and the purchase order, based upon the applicable inspection and test methods. The purchaser shall notify the manufacturer of any pipe pile that has been rejected, and the disposition of such pipe piles shall be subject to agreement between the manufacturer and the purchaser.

20.2 It shall be permissible for the purchaser to set aside any pipe pile that is found in fabrication or installation within the scope of this specification to be unsuitable for the intended end use, based on the requirements of this specification. The purchaser shall notify the manufacturer of any pipe pile that has been set aside. Such pipe piles shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. The disposition of such pipe piles shall be subject to agreement between the manufacturer and the purchaser.

21. Certification

21.1 Where specified in the purchase order, the manufacturer shall furnish a certificate of compliance stating that the pipe pile was manufactured, tested, and inspected in accordance with the requirements of this specification (including year date) and any requirements specified in the purchase order, and was found to meet such requirements, and shall furnish a test report containing the results of the applicable heat analyses, product analyses, and tension tests.

22. Product Marking

22.1 Each length of pipe pile shall be legibly marked by stenciling, stamping, or rolling to show: the name or brand of the manufacturer; the heat number; the process of manufacture (seamless, flash welded, fusion welded, or electric resistance welded), the type of helical seam (helical-lap or helical-butt), if applicable; the outside diameter, nominal wall thickness, length, and weight per unit length; the specification designation (year date not required); and the grade.

22.2 *Bar Coding*—In addition to the requirements in 22.1, it shall be permissible for bar coding to be used as a supplementary identification method; when a specific bar coding system is specified in the purchase order, that system shall be used.

23. Keywords

23.1 seamless steel pipe; steel piles; steel pipe; welded steel pipe

APPENDIX

(Nonmandatory Information)

X1. Minimum Permissible Pipe Wall Thicknesses on Inspection

X1.1 See Table X1.1for minimum wall thicknesses.

TABLE X1.1 Table of Minimum Wall Thicknesses on Inspection for Nominal (Average) Pipe Wall Thicknesses

NOTE 1—The following equation, upon which this table is based, may be applied to calculate minimum wall thickness from nominal (average) wall thickness:

$$t_n \times 0.875 = t_m$$

where:

t_n = nominal wall thickness, in., and
t_m = minimum permissible wall thickness, in.

The wall thickness is expressed to three decimal places, with rounding being in accordance with Practice E 29.

NOTE 2—This table is a master table covering some of the nominal wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of these nominal wall thicknesses are necessarily obtainable.

Nominal Wall Thickness (t_n), in.[A]	Minimum Permissible Wall Thickness on Inspection (t_m), in.[A]	Nominal Wall Thickness (t_n), in.[A]	Minimum Permissible Wall Thickness on Inspection (t_m), in.[A]	Nominal Wall Thickness (t_n), in.[A]	Minimum Permissible Wall Thickness on Inspection (t_m), in.[A]
0.068	0.060	0.276	0.242	0.674	0.590
0.088	0.077	0.277	0.242	0.687	0.601
0.091	0.080	0.279	0.244	0.719	0.629
0.095	0.083	0.280	0.245	0.750	0.656
0.109	0.095	0.281	0.246	0.812	0.710
0.113	0.099	0.294	0.257	0.843	0.738
0.119	0.104	0.300	0.262	0.864	0.756
0.120	0.105	0.307	0.269	0.875	0.766
0.125	0.109	0.308	0.270	0.906	0.793
0.126	0.110	0.312	0.273	0.937	0.820
0.133	0.116	0.318	0.278	0.968	0.847
0.134	0.117	0.322	0.282	1.000	0.875
0.140	0.122	0.330	0.289	1.031	0.902
0.141	0.123	0.337	0.295	1.062	0.929
0.145	0.127	0.343	0.300	1.093	0.956
0.147	0.129	0.344	0.301	1.125	0.984
0.150	0.131	0.358	0.313	1.156	1.012
0.154	0.135	0.365	0.319	1.218	1.066
0.156	0.136	0.375	0.328	1.250	1.094
0.164	0.143	0.382	0.334	1.281	1.121
0.172	0.150	0.400	0.350	1.312	1.148
0.179	0.157	0.406	0.355	1.343	1.175
0.187	0.164	0.432	0.378	1.375	1.203
0.188	0.164	0.436	0.382	1.406	1.230
0.191	0.167	0.437	0.382	1.438	1.258
0.200	0.175	0.438	0.383	1.500	1.312
0.203	0.178	0.469	0.410	1.531	1.340
0.216	0.189	0.500	0.438	1.562	1.367
0.218	0.191	0.531	0.465	1.593	1.394
0.219	0.192	0.552	0.483	1.750	1.531
0.226	0.198	0.562	0.492	1.781	1.558
0.230	0.201	0.593	0.519	1.812	1.586
0.237	0.207	0.600	0.525	1.968	1.722
0.250	0.219	0.625	0.547	2.062	1.804
0.258	0.226	0.656	0.574	2.343	2.050

[A] 1 in. = 25.4 mm

Designation: A 250/A 250M – 05

Standard Specification for Electric-Resistance-Welded Ferritic Alloy-Steel Boiler and Superheater Tubes[1]

This standard is issued under the fixed designation A 250/A 250M; 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 several grades, designated T1, T1a, T1b, T2, T11, T12 and T22, of minimum-wall-thickness, electric-resistance-welded, carbon-molybdenum and chromium-molybdenum alloy-steel, boiler and superheater tubes.

1.2 The tubing sizes and thicknesses usually furnished to this specification are ½ to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.320 in. [0.9 to 8.1 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 An optional supplementary requirement is provided for non-destructive examination for certain ASME applications.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as the 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:* [3]

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing

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 (electric-resistance-welded tubes),

3.1.3 Grade (Table 1),

3.1.4 Size (outside diameter or minimum wall thickness),

3.1.5 Length (specific or random),

3.1.6 Optional requirement (7.3.6),

3.1.7 Test report required (see 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 Product furnished under this specification shall conform to the applicable requirements of Specification A 1016/A 1016M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 1016/A 1016M constitutes nonconformance with this specification. In case of conflicts with the requirements of this specification and Specification A 1016/A 1016M, this specification shall prevail.

5. Materials and Manufacture

5.1 The steel shall be killed.

5.2 The tubes shall be made by electric-resistance welding.

5.3 *Heat Treatment*

5.3.1 After welding, or when cold finished, after the final cold-drawing pass, all tubes shall be heat treated and, except as provided in 5.3.2, furnished in the full annealed, isothermal annealed, normalized, or normalized and tempered condition at the option of the manufacturer. If furnished in the normalized and tempered condition, the minimum tempering temperature

[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.

Current edition approved March 1, 2005. Published March 2005. Originally approved in 1941. Last previous edition approved in 2004 as A 250/A 250M – 04.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-250 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.

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

TABLE 1 Chemical Requirements

Element	Composition, %						
	Grade T1	Grade T1a	Grade T1b	Grade T2	Grade T11	Grade T12	Grade T22
Carbon	0.10–0.20	0.15–0.25	0.14 max	0.10–0.20	0.05–0.15	0.05–0.15	0.15 max
Manganese	0.30–0.80	0.30–0.80	0.30–0.80	0.30–0.61	0.30–0.60	0.30–0.61	0.30–0.60
Phosphorus, max	0.025	0.025	0.025	0.025	0.025	0.030	0.025
Sulfur, max	0.025	0.025	0.025	0.020	0.020	0.020	0.020
Silicon	0.10–0.50	0.10–0.50	0.10–0.50	0.10–0.30	0.50–1.00	0.50 max	0.50 max
Molybdenum	0.44–0.65	0.44–0.65	0.44–0.65	0.44–0.65	0.44–0.65	0.44–0.65	0.87–1.13
Chromium	. . .	. . .	. . .	0.50–0.81	1.00–1.50	0.80–1.25	1.90–2.60

shall be 1200 °F [650 °C], except T22 shall be tempered at 1250 °F [676 °C] minimum.

5.3.2 When grades T1, T1a, T1b, and T2 are cold finished, the tubes may, at the option of the manufacturer, be heat treated after the final cold-drawing pass at a temperature of 1200 °F or higher, provided one of the heat treatments specified in 5.3.1 was applied after welding.

6. Chemical Composition

6.1 The steel shall conform to the requirements given in Table 1.

6.2 *Product Analysis*

6.2.1 An analysis of either one length of flat-rolled stock or one tube shall be made on each heat. The chemical composition thus determined shall conform to the requirements given in Table 1.

6.2.2 If the original test for product analysis fails, retests of two additional 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 (See 8.1) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes that do not meet the requirements of the specification shall be rejected.

7. Mechanical Requirements

7.1 *Tensile Requirements*

7.1.1 The material shall conform to the requirements as to tensile properties given in Table 2.

7.1.2 Table 3 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 given in Table 3, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00\ [E = 1.87t + 15.00]$$

where:

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

7.2 *Hardness Requirements*—The tubes shall have a hardness not exceeding the values given in Table 4.

7.3 *Mechanical Tests Required*

7.3.1 *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 (See 8.2).

7.3.2 *Flattening Test*—One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flange test, from each lot (See 8.1).

7.3.3 *Flange Test*—One flange test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (See 8.1).

7.3.4 *Reverse Flattening Test*—One reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

7.3.5 *Hardness Test*—Brinell and Rockwell hardness tests shall be made on specimens from two tubes from each lot (See 8.2).

7.3.6 *Hydrostatic or Nondestructive Electric Tests*—Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which is to be used.

8. Sampling

8.1 For flattening and flange requirements, the term *lot* applies to all tubes prior to cutting of the same specified outside diameter and specified wall thickness that 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 that 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

TABLE 2 Tensile Requirements

Grade	T1	T1a	T1b	T2	T11	T12	T22
Tensile strength, min, ksi [MPa]	55 [380]	60 [415]	53 [365]	60 [415]	60 [415]	60 [415]	60 [415]
Yield strength, min, ksi [MPa]	30 [205]	32 [220]	28 [195]	30 [205]	30 [205]	32 [220]	30 [205]
Elongation in 2 in. or 50 mm, min, %	30	30	30	30	30	30	30
For longitudinal strip tests a deduction shall be made 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 points	1.50[A]	1.50[A]	1.50[A]	1.50[A]	1.50[A]	1.50[A]	1.50[A]

[A] See Table 3 for the computed minimum values.

TABLE 3 Minimum Elongation Values

Wall Thickness		Elongation in 2 in. or 50 mm, min,%[A]
in.	mm	Grades T1, T1a, T1b, T2, T11, T12, and T22
5⁄16 (0.312)	8	30
9⁄32 (0.281)	7.2	29
1⁄4 (0.250)	6.4	27
7⁄32 (0.219)	5.6	26
3⁄16 (0.188)	4.8	24
5⁄32 (0.156)	4	22
1⁄8 (0.125)	3.2	21
3⁄32 (0.094)	2.4	20
1⁄16 (0.062)	1.6	18

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

TABLE 4 Hardness Requirements

Grade	Brinell Hardness Number (Tubes 0.200 in. [5.1 mm] and over in wall thickness), HBW	Rockwell Hardness Number (Tubes less than 0.200 in. [5.1 mm] in wall thickness), HRB
T1	146	80
T1a	153	81
T1b	137	77
T2	163	85
T11	163	85
T12	163	85
T22	163	85

from the same heat in a lot shall be determined from the size of the tubes given in Table 5.

8.2 For tensile and hardness test requirements, the term *lot* applies to all tubes prior to cutting, of the same specified outside diameter and specified wall thickness that 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 that 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.

9. Forming Operations

9.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects.

TABLE 5 Number of Tubes in a Lot Heat Treated by the Continuous Process

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
Less than 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 wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

10. Product Marking

10.1 In addition to the marking prescribed in Specification A 1016/A 1016M, the marking shall include the words “Electric Resistance-Welded Steel.”

11. Keywords

11.1 boiler tube; resistance welded steel tube; steel tube, alloy; superheater tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order and the necessary tests shall be made at the mill.

S1. Additional Testing of Welded Tubing for 100 % Joint Efficiency in Certain ASME Applications

S1.1 Where this supplement is specified in the purchase order, in certain ASME applications it is permissible to use 100 % joint efficiency for the longitudinal weld, provided the following additional requirements are met:

S1.1.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 1016/A 1016M.

S1.1.2 If Practice E 273 is employed, a 100 % volumetric inspection of the entire length of each tube shall also be performed using one of the non-destructive electric tests permitted by Specification A 1016/A 1016M.

S1.1.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S1.1.4 In addition to the marking prescribed in Specification A 1016/A 1016M, "S1" shall be added after the grade designation.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 250/A 250M – 04, that may impact the use of this specification. (Approved March 1, 2005)

(*1*) Clarified when ASME request applied in S1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 250/A 250M – 95(2001), that may impact the use of this specification. (Approved March 1, 2004)

(*1*) Revised and reformatted extensively to adopt the new general requirements specification and conform to the guidelines for form and style.

Standard Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes[1]

This standard is issued under the fixed designation A 249/A 249M; 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*

1.1 This specification[2] covers nominal-wall-thickness welded tubes and heavily cold worked welded tubes made from the austenitic steels listed in Table 1, with various grades intended for such use as boiler, superheater, heat exchanger, or condenser tubes.

1.2 Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, and TP348H are modifications of Grades TP304, TP309S, TP309Cb, TP310S, TP310Cb, TP316, TP321, TP347, and TP348, and are intended for high-temperature service such as for superheaters and reheaters.

1.3 The tubing sizes and thicknesses usually furnished to this specification are ⅛ in. [3.2 mm] in inside diameter to 12 in. [304.8 mm] in outside diameter and 0.015 to 0.320 in. [0.4 to 8.1 mm], inclusive, in wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.4 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.5 Optional supplementary requirements are provided and, when one or more of these are desired, each shall be so stated in the order.

1.6 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.

1.7 The following safety hazards caveat pertains only to the test method described in the Supplementary Requirements of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific warning statement is given in Supplementary Requirement S7, Note S7.1.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 480/A 480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 112 Test Methods for Determining Average Grain Size

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing

E 527 Practice for Numbering Metals and Alloys (UNS)

2.2 *ASME Boiler and Pressure Vessel Code:*

Section VIII [4]

2.3 *Other Standard:*

SAE J1086 Practice for Numbering Metals and Alloys (UNS)[5]

3. Ordering Information

3.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this

[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-249 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, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[5] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

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

specification. Such requirements may include, but are not limited to, the following:

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

3.1.2 Name of material welded tubes (WLD) or heavily cold worked tubes (HCW),

3.1.3 Grade (Table 1),

3.1.4 Size (outside diameter and nominal wall thickness),

3.1.5 Length (specific or random),

3.1.6 Optional requirements (13.6),

3.1.7 Test report required (see 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. Manufacture

5.1 The welded (WLD) tubes shall be made from flat-rolled steel by an automatic welding process with no addition of filler metal.

5.1.1 Subsequent to welding and prior to final heat treatment, the tubes shall be cold worked either in both weld and base metal or in weld metal only. The method of cold working may be specified by the purchaser. When cold drawn, the purchaser may specify the minimum amount of reduction in cross-sectional area or wall thickness, or both.

5.1.2 Heavily cold worked (HCW) tubes shall be made by applying cold working of not less than 35 % reduction in both wall and weld to a welded tube prior to the final anneal. No filler metal shall be used in the making of the weld. Prior to cold working, the weld shall be 100 % radiographically inspected in accordance with the requirements of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, latest revision, Paragraph UW 51.

TABLE 1 Chemical Requirements, %[A]

Grade	UNS Designation[B]	Composition, %										
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen[C]	Copper	Other
TP 201	S20100	0.15	5.50–7.5	0.060	0.030	1.00	16.0–18.0	3.5–5.5	...	0.25	...	...
TP 202	S20200	0.15	7.5–10.0	0.060	0.030	1.00	17.0–19.0	4.0–6.0	...	0.25	...	...
TPXM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	0.20–0.40	...	Cb 0.10–0.30 V 0.10–0.30
TPXM-29	S24000	0.08	11.5–14.5	0.060	0.030	1.00	17.0–19.0	2.3–3.7	...	0.20–0.40	...	...
TP304	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...
TP304L[D]	S30403	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	...	...	...	...
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...
...	S30415	0.04–0.06	0.80	0.045	0.030	1.00–2.00	18.0–19.0	9.0–10.	...	0.12–0.18	...	Ce 0.03–0.08
TP304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	0.10–0.16	...	...
TP304LN[D]	S30453	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	0.10–0.16	...	...
TP305	S30500	0.12	2.00	0.045	0.030	1.00	17.0–19.0	11.0–13.0	...	...	...	...
...	S30615	0.16–0.24	2.00	0.030	0.030	3.2–4.0	17.0–19.5	13.5–16.0	...	...	...	...
...	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	...	0.14–0.20	...	Ce 0.03–0.08
TP309S	S30908	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	...	...	...	...
TP309H	S30909	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	...	...	...	...

TABLE 1 *Continued*

Grade	UNS Designation[B]	Composition, %										
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen[C]	Copper	Other
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	...	...	...	Cb 10x C-1.10
TP309HCb	S30941	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	...	...	...	Cb 10x C-1.10
TP310S	S31008	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...	...
TP310H	S31009	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...	...
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00	14.0–26.0	18.0–22.0	...	...	...	Cb 10x C-1.10
TP310HCb	S31041	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...	Cb 10x C-1.10
...	S31050	0.030	2.00	0.030	0.015	0.40	24.0–26.0	21.0–23.0	2.00–3.00	0.10–0.16	...	...
...	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	0.18–0.25	0.50–1.00	...
...	S31277	0.020	3.00	0.030	0.010	0.50	20.5–23.0	26.0–28.0	6.5–8.0	0.30–0.40	0.50–1.50	...
TP316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...
TP316L[D]	S31603	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...
TP316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	0.10–0.16	...	...
TP316LN[D]	S31653	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	0.10–0.16	...	...
TP317	S31700	0.08	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...	...
TP317L	S31703	0.030	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...	...

TABLE 1 *Continued*

Grade	UNS Designation[B]	Composition, %										
		Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen[C]	Copper	Other
...	S31725	0.030	2.00	0.045	0.030	1.00	18.0–20.0	13.5–17.5	4.0–5.0	0.20	...	...
...	S31726	0.030	2.00	0.045	0.030	1.00	17.0–20.0	14.5–17.5	4.0–5.0	0.10–0.20	...	...
...	S31727	0.030	1.00	0.030	0.030	1.00	17.5–19.0	14.5–16.5	3.8–4.5	0.15–0.21	2.8–4.0	...
...	S32050	0.030	1.50	0.035	0.020	1.00	22.0–24.0	20.0–23.0	6.0–6.8	0.21–0.32	0.40	...
...	S32053	0.030	1.00	0.030	0.010	1.00	22.0–24.0	24.0–26.0	5.0–6.0	0.17–0.22	...	...
TP321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	0.10	...	Ti 5(C+N)-0.70
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	0.10	...	Ti 5(C+N)-0.70
...	S32654	0.020	2.0–4.0	0.030	0.005	0.50	24.0–25.0	21.0–23.0	7.0–8.0	0.45–0.55	0.30–0.60	...
...	S33228	0.04–0.08	1.00	0.020	0.015	0.30	26.0–28.0	31.0–333.0	...	...	...	Cb 0.60–1.00 Ce 0.05–0.10 Al0.025
...	S34565	0.030	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	0.40–0.60	...	Cb 0.10
TP347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	Cb 10xC-1.10
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	Cb 8xC-1.10
TP348	S34800	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	(Cb+Ta) 10xC-1.10 Ta 0.10 Co 0.20
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	(Cb+Ta) 8xC-1.10 Ta 0.10 Co 0.20
...	S35045	0.06–0.10	1.50	0.045	0.015	1.00	25.0–29.0	32.0–37.0	...	...	0.75	Al 0.15–0.60 Ti 0.15–0.60
TPXM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.0–19.0	17.5–18.5	...	...	...	...
...	S38815	0.030	2.00	0.040	0.020	5.5–6.5	13.0–15.0	15.0–17.0	0.75–1.50	...	0.75–1.50	Al 0.30 max
...	N08367	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	6.0–7.0	0.18–0.25	0.75	...
...	N08926	0.020	2.00	0.030	0.010	0.50	19.0–21.0	24.0–26.0	6.0–7.0	0.15–0.25	0.50–1.50	...
...	N08904	0.020	2.00	0.040	0.030	1.00	19.0–23.0	23.0–28.0	4.0–5.0	0.10	1.00–2.00	...

[A] Maximum, unless otherwise indicated.
[B] New designation established in accordance with Practice E 527 and SAE J1086.
[C] The method of analysis for nitrogen shall be a matter of agreement between the purchaser and manufacturer.
[D] For small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040 % is necessary in Grades TP 304L and TP 316L. Small outside diameter tubes are defined as those less than 0.500 in. [12.7 mm] in outside diameter and light wall are those less than 0.049 in. [1.2 mm] in minimum wall thickness.

6. Heat Treatment

6.1 All material shall be furnished in the heat-treated condition in accordance with the requirements of Table 2.

6.2 A solution annealing temperature above 1950 °F [1065 °C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S4).

7. Chemical Composition

7.1 The heat analysis shall conform to the requirements as to chemical composition given in Table 1.

8. Product Analysis

8.1 An analysis of either 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 given in Section 7.

8.2 A product analysis tolerance of Table A1.1 in Specification A 480/A 480M shall apply. The product analysis tolerance is not applicable to the carbon content for material with a specified maximum carbon of 0.04 % or less.

8.3 If the original test for product analysis fails, retests of two additional 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 (See Note 1) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes that do not meet the requirements of the specification shall be rejected.

NOTE 1—For flattening 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 3.

NOTE 2—For tension 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

TABLE 2 Heat Treatment Requirements

Grade	UNS Number	Solutioning Temperature, min or range	Quenching Method
All grades not individually listed below		1900 °F [1040 °C]	A
...	S30815	1920 °F [1050 °C]	B
TP309HCb	S30941	1900 °F [1040 °C]C	B
TP310H	S31009	1900 °F [1040 °C]	B
TP310HCb	S31041	1900 °F [1040 °C]C	B
...	S31254	2100 °F [1150 °C]	B
...	S31277	2050 °F [1120 °C]	B
TP316H	S31609	1900 °F [1040 °C]	B
...	S31727	1975 °F [1080 °C]–2155 °F [1180 °C]	B
...	S32053	1975 °F [1080 °C]–2155 °F [1180 °C]	B
TP321	S32100	1900 °F [1040 °C]C	B
TP321H	S32109	2000 °F [1100 °C]C	B
...	S32654	2100 °F [1150 °C]	B
...	S33228	2050 °F [1120 °C]	B
...	S34565	2050 °F [1120 °C]–2140 °F [1170 °C]	B
TP347	S34700	1900 °F [1040 °C]C	B
TP347H	S34709	2000 °F [1100 °C]C	B
TP348	S34800	1900 °F [1040 °C]C	B
TP348H	S34809	2000 °F [1100 °C]C	B
...	S35045	2000 °F [1100 °C]	D
...	S38815	1950 °F [1065 °C]	B
...	N08367	2025 °F [1110 °C]	B
...	N08904	2000 °F [1100 °C]	B
...	N08926	2010 °F [1105 °C]	B

A Quenched in water or rapidly cooled by other methods, at a rate sufficient to prevent reprecipitation of carbides, as demonstrated by the capability of passing Practices A 262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (See Supplementary Requirement S6). Note that Practices A 262 requires the test to be performed on sensitized specimens in the low carbon and stabilized types and on specimens representative of the as-shipped condition of the other types. In the case of low-carbon types containing 3 % or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and purchaser.

B Quenched in water or rapidly cooled by other methods.

C A solution treating temperature above 1950 °F [1065 °C] may impair resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in the indicated grades. When specified by the purchaser, a lower temperature stabilization or re-solution anneal shall be used subsequent to the higher-temperature solution anneal prescribed in this table (See Supplementary Requirement S4).

D Cooled in still air, or faster.

TABLE 3 Number of Tubes in a Lot Heat Treated by the Continuous Process

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
Less than 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 wall thickness	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

include all tubes of the same size and heat, annealed in the same furnace at the same temperature, time at heat, and furnace speed.

9. Tensile Requirements

9.1 The material shall conform to the tensile properties prescribed in Table 4.

10. Hardness Requirements

10.1 The tubes shall have a Rockwell hardness number not exceeding the values specified in Table 4.

11. Reverse-Bend Test Requirement

11.1 A section 4 in. [100 mm] minimum in length shall be split longitudinally 90° on each side of the weld. The sample shall then be opened and bent around a mandrel with a maximum thickness of four times the wall thickness, with the mandrel parallel to the weld and against the original outside surface of the tube. The weld shall be at the point of maximum bend. There shall be no evidence of cracks, or of overlaps resulting from the reduction in thickness of the weld areas by cold working. When the geometry or size of the tubing make it difficult to test the sample as a single piece, the sample may be sectioned into smaller pieces provided a minimum of 4 in. of weld is subjected to reverse bending.

NOTE 3—The reverse bend test is not applicable when the specified wall is 10 % or more of the specified outside diameter, or the wall thickness is 0.134 in. [3.4 mm] or greater, or the outside diameter size is less than 0.375 in. [9.5 mm]. Under these conditions the reverse flattening test of Specification A 1016/A 1016M shall apply.

12. Grain Size Requirement

12.1 The grain size of Grades TP309H, TP309HCb, TP310H and TP310HCb, as determined in accordance with Test Methods E 112, shall be No. 6 or coarser.

12.2 The grain size of Grades TP304H, TP316H, TP321H, TP347H and TP348H, as determined in accordance with Test Methods E 112, shall be No. 7 or coarser.

13. Mechanical Tests and Grain Size Determinations Required

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 (See Note 2).

13.2 *Flattening Test*—One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flange test, from each lot (See Note 1).

TABLE 4 Tensile and Hardness Requirements[A]

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %	Rockwell Hardness Number, max
TP201	S20100	95 [655]	38 [260]	35	B95
TP202	S20200	90 [620]	38 [260]	35	B95
TPXM-19	S20910	100 [690]	55 [380]	35	C25
TPXM-29	S24000	100 [690]	55 [380]	35	B100
. . .	S24565	115 [795]	60 [415]	35	B100
TP304	S30400	75 [515]	30 [205]	35	B90
TP304L	S30403	70 [485]	25 [170]	35	B90
TP304H	S30409	75 [515]	30 [205]	35	B90
. . .	S30415	87 [600]	42 [290]	35	B96
TP304N	S30451	80 [550]	35 [240]	35	B90
TP304LN	S30453	75 [515]	30 [205]	35	B90
TP305	S30500	75 [515]	30 [205]	35	B90
...	S30615	90 [620]	40 [275]	35	B95
...	S30815	87 [600]	45 [310]	35	B95
TP309S	S30908	75 [515]	30 [205]	35	B90
TP309H	S30909	75 [515]	30 [205]	35	B90
TP309Cb	S30940	75 [515]	30 [205]	35	B90
TP309HCb	S30941	75 [515]	30 [205]	35	B90
TP310S	S31008	75 [515]	30 [205]	35	B90
TP310H	S31009	75 [515]	30 [205]	35	B90
TP310Cb	S31040	75 [515]	30 [205]	35	B90
TP310HCb	S31041	75 [515]	30 [205]	35	B90
...	S31050:				
	t ≤ 0.25 in.	84 [580]	39 [270]	25	B95
	t > 0.25 in.	78 [540]	37 [255]	25	B95
...	S31254:				
	t ≤ 0.187 in. [5.00 mm]	98 [675]	45 [310]	35	B100
	t > 0.187 in. [5.00 mm]	95 [655]	45 [300]	35	B100
...	S31277	112 [770]	52 [360]	40	B100
TP316	S31600	75 [515]	30 [205]	35	B90
TP316L	S31603	70 [485]	25 [170]	35	B90
TP316H	S31609	75 [515]	30 [205]	35	B90
TP316N	S31651	80 [550]	35 [240]	35	B90
TP316LN	S31653	75 [515]	30 [205]	35	B90
TP317	S31700	75 [515]	30 [205]	35	B90
TP317L	S31703	75 [515]	30 [205]	35	B90
...	S31725	75 [515]	30 [205]	35	B90
...	S31726	80 [550]	35 [240]	35	B90
...	S31727	80 [550]	36 [245]	35	B96
...	S32050	98 [675]	48 [330]	40	
...	S32053	93 [640]	43 [295]	40	B96
TP321	S32100	75 [515]	30 [205]	35	B90
TP321H	S32109	75 [515]	30 [205]	35	B90
. . .	S32654	109 [750]	62 [430]	35	B100
...	S33228	73 [500]	27 [185]	30	B90
TP347	S34700	75 [515]	30 [205]	35	B90
TP347H	S34709	75 [515]	30 [205]	35	B90
TP348	S34800	75 [515]	30 [205]	35	B90
TP348H	S34809	75 [515]	30 [205]	35	B90
...	S35045	70 [485]	25 [170]	35	B90
TPXM-15	S38100	75 [515]	30 [205]	35	B90
...	S38815	78 [540]	37 [255]	30	B100
...	N08367				
	t ≤ 0.187	100 [690]	45 [310]	30	100
	t > 0.187	95 [655]	45 [310]	30	100
. . .	N08904	71 [490]	31 [215]	35	B90
. . .	N08926	94 [650]	43 [295]	35	B100

[A] Not applicable to tubes less than ⅛ in. [3.2 mm] in outside diameter or having wall thickness below 0.015 in. [0.4 mm], or both. The tensile properties of such small diameter or thin wall tubes shall be a matter of agreement between the manufacturer and the purchaser.

13.3 *Flange Test*—One flange test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (See Note 1).

13.4 *Reverse-Bend Test*—One reverse-bend test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

13.5 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (See Note 2).

13.6 *Hydrostatic or Nondestructive Electric Test*—Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

13.7 *Grain Size*—Grain size determinations on grades TP309H, TP309HCb, TP310H and TP310HCb shall be made on the same number of tubes as prescribed for the flattening test.

13.8 Heavily cold worked tubes (HCW) shall be capable of passing the weld decay test listed in Supplementary S7 with a weld metal to base metal loss ratio of 0.90 to 1.10. The test is not required unless S7 is specified in the purchase order.

14. Permissible Variations in Dimensions

14.1 Dimensional tolerances other than wall thickness tolerances shall be in accordance with Specification A 1016/A 1016M. Wall thickness tolerances shall be ±10 % of nominal wall for all tubing sizes.

14.2 The wall thickness of the weld shall not exceed the wall thickness measured 90° from the weld by more than 6 % of the specified wall thickness or 0.004 in. [0.1 mm], whichever is greater.

14.2.1 Requirements of 14.2 are not applicable when any of the following apply:

14.2.1.1 When the specified wall thickness exceeds 12 % of the specified outside diameter;

14.2.1.2 When the specified wall thickness exceeds 0.165 in. [4.2 mm];

14.2.1.3 When the specified OD exceeds 3 in. [76.2 mm]; or

14.2.1.4 When the specified minimum yield strength given in Table 4 for the specified grade is 35 ksi [240 MPa] or greater.

15. Workmanship, Finish, and Appearance

15.1 Finished tubes shall have smooth ends free of burrs and shall not deviate from straightness by more than 0.030 in. [0.8 mm] in 3 ft (900 mm] of length.

16. Surface Condition

16.1 The tubes, after final heat treatment, shall be chemically descaled or pickled free of scale. When bright annealing is used, pickling or chemical descaling is not necessary.

17. Forming Operations

17.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. All tubes, when properly manipulated, shall be able to stand expanding and beading without showing cracks and flaws, and also shall stand all forging, welding, and bending operations necessary for application without developing defects.

18. Product Marking

18.1 In addition to the marking prescribed in Specification A 1016/A 1016M, the marking for Grades TP304H, TP309H, TP309HCb, TP310H, TP310HCb, TP316H, TP321H, TP347H, and TP348H shall also include the heat number and the heat-treatment lot identification.

19. Keywords

19.1 austenitic stainless steel; boiler tubes; condenser tube; heat exchanger tube; high temperature applications; steel tube; superheater tubes; temperature service applications, high; welded steel tube and heavily cold worked (HCW) tubes

SUPPLEMENTARY REQUIREMENTS

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

S1. Stress-Relieved Annealed Tubes

S1.1 For use in certain corrosives, particularly chlorides where stress corrosion may occur, tubes in Grades TP304L, TP316L, TP321, TP347, and TP348 may be specified in the stress-relieved annealed condition. Details of these supplemental requirements shall be agreed upon by the manufacturer and the purchaser.

S1.2 When stress-relieved tubes are specified, tubes shall be given a heat treatment at 1550 to 1650 °F [845 to 900 °C] after roll straightening. Cooling from this temperature range may be either in air or by slow cooling. No mechanical straightening is permitted after the stress-relief treatment.

S1.3 Straightness of the tubes shall be a matter of negotiation between the purchaser and manufacturer.

S2. Minimum Wall Tubes

S2.1 When specified by the purchaser, tubes shall be furnished on a minimum wall basis. Such tubes shall satisfy the minimum wall thickness requirements of Specification A 1016/A 1016M rather than the nominal wall requirements of this specification. In addition to the marking required by Section 18, the tubing shall be marked S2.

S3. Air Underwater Pressure Test

S3.1 When specified, the tubing shall be examined by the air underwater pressure test.

S4. Stabilizing Heat Treatment

S4.1 Subsequent to the solution anneal required in Section 6, Grades TP309HCb, TP310HCb, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S5. Unstraightened Tubes

S5.1 When the purchaser specifies tubes unstraightened after final heat treatment (such as coils), the straightness requirement of Section 12 shall not apply and the minimum yield strength of Table 3 shall be reduced by 5 ksi [35 MPa].

S5.2 On the certification, and wherever the grade designation for unstraightened tubing appears, it shall be identified with the suffix letter "U" (for example, 304-U, 321-U, etc.).

S6. Intergranular Corrosion Test

S6.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S6.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S6.2 A stabilization heat treatment in accordance with Supplementary Requirement S4 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

S7. Weld Decay Test

S7.1 This test is not applicable to alloys with a nickel content ≥ 19.0 % or a molybdenum content ≥ 4.00 %, or both.

S7.2 When specified by the purchase order, one sample from each lot of tubing (See Note 2) shall be subjected to testing in a boiling mixture of 50 % reagent grade hydrochloric acid and 50 % water.

S7.3 Approximately 2-in. long samples shall be prepared from a production length of tubing. Shorter, 1-in. samples may be used for small diameter (1/2-in. and below) tubing. Split the sample longitudinally to allow for easy micrometer measurements. The sample may be one piece which contains the weld and at least 90° of base-metal to one side of the weld. Alternately, the sample may be two separate pieces with one containing the weld and a similar size section from the balance of the tube opposite the weld consisting of 100 % base metal. Remove all burrs and sharp edges by lightly grinding. Remove dust and grease by cleaning with soap and water or other suitable solvents. Then, place sample(s) in the flask. It is not recommended to test more than four samples together, or to mix alloy types.

S7.4 Prepare the hydrochloric acid solution by slowly adding reagent grade (approximately 37 %) hydrochloric acid to an equal volume of distilled water. (**Warning—**Protect eyes and use rubber gloves when handling acid. Mixing shall be done under a hood and testing shall be run under a hood.)

S7.5 The test container shall be a 1-L Erlenmeyer flask equipped with ground-glass joints and an Ahlin condenser. The volume of the solution shall be approximately 700 mL.

S7.6 Measure the thickness of the tube at five locations along the weld area and at five locations along the base-metal section. In both cases, take measurements at approximately equal longitudinal intervals along the section lengths. Make these measurements with a sharp pointed micrometer accurate to at least 0.001 in. The micrometer must be suitable for measuring the small features in the surface after testing. Typical pin micrometers have tapered anvils with a tip radius of less than 0.015 in.

S7.7 Immerse the samples into the solution. Add boiling chips and bring to a boil. Allow the chips to remain boiling throughout the test. The time of testing shall be that which is required to remove 40 to 60 % of the original base-metal thickness (usually 2 h or less). If more than 60 % of the base-metal thickness remains, the sample may be removed after 24 h.

S7.8 At the end of the test period, remove the samples from the solution, rinse with distilled water, and dry.

S7.9 After exposure to the test solution, repeat the tube-thickness measurement as in S7.6. If the thinning is not uniform across the width of the weld, then two sets of weld-metal measurement are required. One set of measurements is to be taken along the centerline of the weld. The second set of measurements is to be taken in the thinnest area of the weld.

S7.10 Calculate the corrosion ratio, R, for both sections of the weld as follows in Eq 1:

$$R = \frac{W_o - W}{B_o - B} \tag{1}$$

where:

W_o = average weld-metal thickness before the test,
W = average weld-metal thickness after the test,
B_o = average base-metal thickness before the test, and
B = average base-metal thickness after the test.

S7.10.1 A corrosion ratio of 1.25 or less for the thinnest section of the weld is permissible. Other criteria, such as a ratio of 1.00 or less, may be specified upon agreement between the producer and the purchaser.

S8. Special Applications

S8.1 For special applications, such as hydraulic expansion of tubes into tube sheets, there shall be no dimensional indication of the weld. Tubes ordered to this requirement shall bear the additional marking of NB.

S9. Additional Testing of Welded Tubing per ASME Request

S9.1 Each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 1016/A 1016M.

S9.2 If Practice E 273 is employed, a 100 % volumetric inspection of the entire length of each tube shall also be performed using one of the nondestructive electric tests permitted by Specification A 1016/A 1016M.

S9.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S9.4 In addition to the marking prescribed in Specification A 1016/A 1016M, "S9" shall be added after the grade designation.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 249/A 249M – 04a, that may impact the use of this specification. (Approved September 1, 2007)

(*1*) Added UNS 31727 and S32053 to Table 1, Table 2, and Table 4.

Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service[1]

This standard is issued under the fixed designation A 234/A 234M; 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*

1.1 This specification[2] covers wrought carbon steel and alloy steel fittings of seamless and welded construction covered by the latest revision of ASME B16.9, B16.11, MSS-SP-79, MSS-SP-83, and MSS-SP-95. These fittings are for use in pressure piping and in pressure vessel fabrication for service at moderate and elevated temperatures. Fittings differing from these ASME and MSS standards shall be furnished in accordance with Supplementary Requirement S58 of Specification A 960/A 960M.

1.2 Optional supplementary requirements are provided for fittings where a greater degree of examination is desired. When desired, one or more of these supplementary requirements may be specified in the order.

1.3 This specification does not cover cast welding fittings or fittings machined from castings. Cast steel welding fittings are governed by Specifications A 216/A 216M and A 217/A 217M.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 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.

2. Referenced Documents

2.1 In addition to those reference documents listed in Specification A 960/A 960M, the following list of standards apply to this specification.

2.2 *ASTM Standards:* [3]

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

A 217/A 217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service

A 960/A 960M Specification for Common Requirements for Wrought Steel Piping Fittings

2.3 *ASME Standards:*[4]

B16.9 Steel Butt-Welding Fittings

B16.11 Forged Steel Fittings, Socket Welding and Threaded

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

Section V Nondestructive Examination

Section VIII, Division 1, Pressure Vessels

Section IX Welding Qualifications

2.5 *MSS Standards:*[5]

MSS-SP-25 Standard Marking System for Valves, Fittings, Flanges, and Unions

MSS-SP-79 Socket Welding Reducer Inserts

MSS-SP-83 Steel Pipe Unions, Socket-Welding and Threaded

MSS-SP-95 Swage(d) Nipples and Bull Plugs

2.6 *ASNT Standard:*

SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification[6]

3. Ordering Information

3.1 See Specification A 960/A 960M.

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 960/A 960M, including

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-234 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, Three Park Ave., New York, NY 10016-5990.

[5] Available from Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602.

[6] Available from 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.**

any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 960/A 960M constitutes non-conformance with this specification. In case of a conflict between the requirements of this specification and Specification A 960/A 960M, this specification shall prevail.

5. Materials

5.1 The material for fittings shall consist of killed steel, forgings, bars, plates, seamless or fusion-welded tubular products with filler metal added and shall conform to the chemical requirements of Table 1. Unless otherwise specified for carbon steel plates, the steel may be made to either coarse grain or fine grain practice. Grade WP9 shall be made to fine grain practice.

5.2 A starting material specification that specifically requires the addition of any element beyond those listed for the materials in Table 1 for the applicable grade of material is not permitted. This does not preclude the use of deoxidizers or the judicious use of elements for grain size control.

6. Manufacture

6.1 Forging or shaping operations may be performed by hammering, pressing, piercing, extruding, upsetting, rolling, bending, fusion welding, machining, or by a combination of two or more of these operations. The forming procedure shall be so applied that it will not produce injurious imperfections in the fittings.

NOTE 1—Fittings NPS-4 and under may be machined from hot-forged or rolled, cold-sized, and straightened bar stock having the chemical composition of the Grade in Table 1 and the mechanical properties of the Grade in Table 2. Heat treatment shall be in accordance with Section 7. All caps machined from bar stock shall be examined by liquid penetrant or magnetic particle in accordance with S52 or S53 in Specification A 960/A 960M.

6.2 All welds including welds in tubular products from which fittings are made shall be (*1*) made by welders, welding operators, and welding procedures qualified under the provisions of ASME Section IX, (*2*) heat treated in accordance with Section 7 of this specification, and (*3*) radiographically examined throughout the entire length of each weld in accordance with Article 2, ASME Section V with acceptance limits in accordance with Paragraph UW-51 of ASME Section VIII, Division 1 of the ASME Boiler & Pressure Vessel Code. In place of radiographic examination, welds may be ultrasonically examined in accordance with Appendix 12 of Section VIII. The NDE of welds in Grades WPB, WPC, WP1, WP11 Class 1,

TABLE 1 Chemical Requirements

NOTE 1—All requirements are maximum unless otherwise indicated.
NOTE 2—Where an ellipsis (...) appears in this table, there is no requirement.

Grade and Marking Symbol[A]	Composition, %									
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Chromium	Molybdenum	Nickel	Copper	Others
WPB[B,C,D,E,F]	0.30 max	0.29–1.06	0.050	0.058	0.10 min	0.40 max	0.15 max	0.40 max	0.40 max	Vanadium 0.08 max
WPC[C,D,E,F]	0.35 max	0.29–1.06	0.050	0.058	0.10 min	0.40 max	0.15 max	0.40 max	0.40 max	Vanadium 0.08 max
WP1	0.28 max	0.30–0.90	0.045	0.045	0.10–0.50	. . .	0.44–0.65	. . .	. . .	. . .
WP12 CL1, WP12 CL2	0.05–0.20	0.30–0.80	0.045	0.045	0.60 max	0.80–1.25	0.44–0.65	. . .	. . .	. . . . . .
WP11 CL1	0.05–0.15	0.30–0.60	0.030	0.030	0.50–1.00	1.00–1.50	0.44–0.65	. . .	. . .	. . .
WP11 CL2, WP11 CL3	0.05–0.20	0.30–0.80	0.040	0.040	0.50–1.00	1.00–1.50	0.44–0.65	. . .	. . .	. . . . . .
WP22 CL1, WP22 CL3	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max	1.90–2.60	0.87–1.13	. . .	. . .	. . . . . .
WP5 CL1, WP5 CL3	0.15 max	0.30–0.60	0.040	0.030	0.50 max	4.0–6.0	0.44–0.65	. . .	. . .	. . . . . .
WP9 CL1, WP9 CL3	0.15 max	0.30–0.60	0.030	0.030	1.00 max	8.0–10.0	0.90–1.10	. . .	. . .	. . .
WPR	0.20 max	0.40–1.06	0.045	0.050	. . .	. . .	. . .	1.60–2.24	0.75–1.25	. . .
WP91	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	8.0–9.5	0.85–1.05	0.40 max	. . .	Vanadium 0.18–0.25 Columbium 0.06–0.10 Nitrogen 0.03–0.07 Aluminum 0.02 max[G] Titanium 0.01 max[G] Zirconium 0.01 max[G]
WP911	0.09–0.13	0.30–0.60	0.020	0.010	0.10–0.50	8.5–9.5	0.90–1.10	0.40 max	. . .	Vanadium 0.18–0.25 Columbium 0.060–0.10 Nitrogen 0.04–0.09 Aluminum 0.02 max[G] Boron 0.0003–0.006 Tungsten 0.90–1.10 Titanium 0.01 max[G] Zirconium 0.01 max[G]

[A] When fittings are of welded construction, the grade and marking symbol shown above shall be supplemented by letter "W".
[B] Fittings made from bar or plate may have 0.35 max carbon.
[C] Fittings made from forgings may have 0.35 max carbon and 0.35 max silicon with no minimum.
[D] For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted, up to a maximum of 1.35 %.
[E] The sum of Copper, Nickel, Chromium, and Molybdenum shall not exceed 1.00 %.
[F] The sum of Chromium and Molybdenum shall not exceed 0.32 %.
[G] Applies both to heat and product analyses.

TABLE 2 Tensile Requirements

NOTE 1—Where an ellipsis (...) appears in this table, there is no requirement.

Grade and Marking Symbol	WPB	WPC, WP11 CL2, WP12 CL2	WP1	WP11 CL1, WP22 CL1, WP5 CL1 WP9 CL1	WPR	WP11 CL3, WP22 CL3 WP5 CL3 WP9 CL3	WP91	WP911	WP12 CL1
Tensile strength, range ksi [MPa]	60–95 [415–655]	70–95 [485–655]	55–80 [380–550]	60–85 [415–585]	63–88 [435–605]	75–100 [520–690]	85–110 [585–760]	90–120 [620–840]	60–85 [415–585]
Yield strength, min, ksi [MPa] (0.2 % offset or 0.5 % extension-under-load)	35 [240]	40 [275]	30 [205]	30 [205]	46 [315]	45 [310]	60 [415]	64 [440]	32 [220]

	Elongation Requirements					
	Grades					
	All Grades except WPR, WP91, and WP911		WPR		WP91 WP911	
	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse	Longi-tudinal	Trans-verse
Elongation:						
Standard round specimen, or small proportional specimen, min % in 4 D	22	14	20	...	20	...
Rectangular specimen for wall thickness 5⁄16 in. [7.94 mm] and over, and for all small sizes tested in full section; min % in 2 in. [50 mm]	30	20[A]	28	...	...	...
Rectangular specimen for wall thickness less than 5⁄16 in. [7.94 mm]; min % in 2 in. [50 mm] (1⁄2-in. [12.7-mm] wide specimen)	[B]	[B]	[B]	...	...	...

[A] WPB and WPC fittings manufactured from plate shall have a minimum elongation of 17 %.

[B] For each 1⁄32 in. [0.79 mm] decrease in wall thickness below 5⁄16 in. [7.94 mm], a deduction of 1.5 % for longitudinal and 1.0 % for transverse from the values shown above is permitted. The following table gives the minimum value for various wall thicknesses.

Wall Thickness		Grades			
		All Grades except WPR, WP91 and WP911		WPR	WP91 and WP911
in.	[mm]	Longitudinal	Transverse	Longitudinal	Longitudinal
5⁄16 (0.312)	7.94	30.0	20.0	28.0	20
9⁄32 (0.281)	7.14	28.5	19.0	26.5	19
1⁄4 (0.250)	6.35	27.0	18.0	25.0	18
7⁄32 (0.219)	5.56	25.5	...	23.5	17
3⁄16 (0.188)	4.76	24.0	...	22.0	16
5⁄32 (0.156)	3.97	22.5	...	20.5	15
1⁄8 (0.125)	3.17	21.0	...	19.0	14
3⁄32 (0.094)	2.38	19.5	...	17.5	13
1⁄16 (0.062)	1.59	18.0	...	16.0	12

Note—This table gives the computed minimum % elongation value for each 1⁄32 in. [0.79 mm] decrease in wall thickness. Where the wall thickness lies between two values above, the minimum elongation value is determined by the following equations:

Direction of Test	Equation
Longitudinal	$E = 48t + 15.00$
Transverse	$E = 32t + 10.00$

where:

E = elongation in 2 in. or [50 mm], %, and

t = actual thickness of specimen, in. [mm].

WP11 Class 2, WP11 Class 3, WP12 Class 1, WP12 Class 2, and WPR may be performed either prior to or after forming. NDE of welds in Grades WP5, WP9, WP91, WP911, WP22 Class 1, and WP22 Class 3 shall be done after forming.

6.3 Personnel performing NDE examinations shall be qualified in accordance with SNT-TC-1A.

6.4 The welded joints of the fittings shall be finished in accordance with the requirements of Paragraph UW-35 (*a*) of ASME Section VIII, Division 1.

6.5 All butt-weld tees manufactured by cold-forming method(s) shall be liquid penetrant or magnetic particle examined by one of the methods specified in Supplementary Requirement S52 or S53 in Specification A 960/A 960M. This examination shall be performed after final heat treat. Only the side wall area of the tees need be examined. This area is defined by a circle that covers the area from the weld bevel of the branch outlet to the center line of the body or run. Internal and external surfaces shall be examined when size permits accessibility. No cracks shall be permitted. Other imperfections shall be treated in accordance with Section 13 on Surface Quality. After the removal of any crack, the tee(s) shall be re-examined by the original method. Acceptable tees shall be marked with the symbol PT or MT, as applicable, to indicate compliance.

6.6 Stubends may be produced with the entire lap added by the welding of a ring, made from plate or bar of the same alloy grade and composition, to the outside of a straight section of pipe, provided the weld is double welded, is a full penetration joint, satisfies the requirements of 6.2 for qualifications and 7.3.3 for post weld heat treatment.

7. Heat Treatment

7.1 *Heat Treatment Procedures*—Fittings, after forming at an elevated temperature, shall be cooled to a temperature below the critical range under suitable conditions to prevent injurious defects caused by too rapid cooling, but in no case more rapidly than the cooling rate in still air. Heat treatment temperatures specified are metal (part) temperatures. Heat-treated fittings shall be treated according to paragraph 7 in Specification A 960/A 960M.

7.2 *WPB, WPC, and WPR Fittings*:

7.2.1 Hot-formed WPB, WPC, and WPR fittings upon which the final forming operation is completed at a temperature above 1150 °F [620 °C] and below 1800 °F [980 °C] need not be heat treated provided they are cooled in still air.

7.2.2 Hot-formed or forged WPB, WPC, and WPR fittings finished at temperature in excess of 1800 °F [980 °C] shall subsequently be annealed, normalized, or normalized and tempered. Hot-forged fittings NPS 4 or smaller need not be heat treated.

7.2.3 WPB, WPC, and WPR fittings over NPS 12, produced by locally heating a portion of the fitting stock to any temperature for forming, shall be subsequently annealed, normalized, or normalized and tempered. Fittings such as elbows, tees, header tees, reducers and lap joint stub ends with a carbon content less than 0.26 %, NPS 12 and under, shall not require heat treatment after forming a locally heated portion of the fitting.

7.2.4 Cold-formed WPB, WPC, and WPR fittings, upon which the final forming operation is completed at a temperature below 1150 °F [620 °C], shall be normalized, or shall be stress relieved at 1100 to 1275 °F [595 to 690 °C].

7.2.5 WPB, WPC, and WPR fittings produced by fusion welding and having a nominal wall thickness at the welded joint of ¾ in. [19 mm] or greater shall be post-weld heat treated at 1100 to 1250 °F [595 to 675 °C], or in accordance with 7.2.6.

7.2.6 At the option of the manufacturer, WPB and WPC fittings produced by any of the methods in Section 6 may be annealed, normalized, or normalized and tempered.

7.3 *Fittings Other than WPB, WPC, and WPR*:

7.3.1 Fittings of Grades WP1, WP11 Class 1, WP11 Class 2, WP11 Class 3, WP12 Class 1, WP12 Class 2, WP22 Class 1, WP22 Class 3, WP5, and WP9 shall be furnished in the full-annealed, isothermal-annealed, or normalized and tempered condition. If normalized and tempered, the tempering temperature for WP11 Class 1, WP11 Class 2, WP11 Class 3, WP12 Class 1, and WP12 Class 2 shall not be less than 1150 °F [620 °C]; for Grades WP5, WP9, WP22 Class 1, and WP22 Class 3 the tempering temperature shall not be less than 1250 °F [675 °C].

7.3.2 Fittings of Grades WP1, WP12 Class 1, or WP12 Class 2 either hot formed or cold formed may be given a final heat treatment at 1200 °F [650 °C] instead of the heat treatment specified in 7.3.1.

7.3.3 Fittings in all thicknesses produced by fusion welding after the heat treatment specified in 7.3.1 shall be post-weld heat treated at a temperature not less than prescribed above for tempering except that Grade WP1 is required to be post-weld heat treated only when the nominal wall thickness at the welded joint is ½ in. [13 mm] or greater.

7.3.4 Except when Supplementary Requirement S1 is specified by the purchaser, Grade WP91 shall be normalized at 1900 °F [1040 °C] minimum, and 1975 °F [1080 °C] maximum, and tempered in the temperature range of 1350 °F [730 °C] to 1470 °F [800 °C] as a final heat treatment.

7.3.5 Grade WP911 shall be normalized in the temperature range of 1900 to 1975 °F [1040 to 1080 °C], and tempered in the temperature range of 1365 to 1435 °F [740 to 780 °C] as a final heat treatment.

7.4 *WPB and WPC Fittings Made from Bar*— Cold-finished bars reduced in cross-sectional area more than 10 % by cold drawing or cold rolling are not acceptable for use in the manufacture of these fittings unless the bars have been either stress relieved in the temperature range of 1100 to 1250 °F [595 to 675 °C], normalized, normalized and tempered, or fully annealed. Mechanical testing must be performed subsequent to the final heat-treating operation.

7.5 Liquid quenching followed by tempering shall be permitted for all grades when approved by the purchaser. Minimum tempering temperature shall be 1100 °F [595 °C] for WPB, WPC, and WPR, 1150 °F [620 °C] for Grades WP1, WP11 Class 1, WP11 Class 2, WP11 Class 3, WP 12 Class 1, and WP12 Class 2 and 1250 °F [675 °C] for Grades WP5, WP9, WP22 Class 1, and WP22 Class 3, and 1350 °F [730 °C] for Grade WP91 and WP911.

8. Chemical Composition

8.1 The chemical composition of each cast or heat used shall be determined and shall conform to the requirements of the chemical composition for the respective materials listed in Table 1. The ranges as shown have been expanded to include variations of the chemical analysis requirements that are listed in the various specifications for the starting materials (pipe, tube, plate, bar, and forgings) normally used in the manufacturing of fittings to this specification.

8.2 The steel shall not contain any unspecified elements for the ordered grade to the extent that it conforms to the requirements of another grade for which that element is a specified element having a required minimum content.

8.3 Weld metal used in the construction of carbon-steel fittings shall be mild steel analysis No. A1 of Table QW-442, Section IX of the ASME Boiler and Pressure Vessel Code, No. A2 may be used for Grade WPCW.

8.4 The molybdenum and chromium content of the deposited weld metal of alloy steel fittings shall be within the same percentage range as permitted for the base metal.

9. Tensile Requirements

9.1 The tensile properties of the fitting material shall conform to the requirements listed in Table 2.

9.1.1 Specimens cut either longitudinally or transversely shall be acceptable for the tension test.

9.1.2 While Table 2 specifies elongation requirements for both longitudinal and transverse specimens, it is not the intent that both requirements apply simultaneously. Instead, it is intended that only the elongation requirement that is appropriate for the specimen used be applicable.

9.2 One tension test shall be made on each heat of material and in the same condition of heat treatment as the finished fittings it represents. The sample thickness shall not vary more than ¼ in. [6 mm] from the fitting wall thickness it represents.

9.3 When cold-formed fittings are furnished, samples of the raw material shall be normalized or stress relieved as required in 7.2.4. Tension tests conducted on these heat-treated samples shall be considered to be the tensile properties of the cold-formed fittings.

9.4 Records of the tension tests shall be certification that the material of the fitting meets the tensile requirements of this specification provided the heat treatments are the same. If the raw material was not tested, or the fitting is not in the same condition of heat treatment, the fitting manufacturer shall perform the required test on material representative of the finished fitting from each heat of starting material.

10. Hardness

10.1 Fittings shall be capable of meeting the following hardness requirements, if tested:

10.1.1 Fittings of Grades WP5, WP9, and WPR—217 HB maximum.

10.1.2 Fittings of Grade WP91 and WP911—248 HB maximum.

10.1.3 Fittings of all other grades—197 HB maximum.

10.2 When actual hardness testing of the fittings is required, see Supplementary Requirement S57 in Specification A 960/A 960M.

11. Hydrostatic Tests

11.1 See Specification A 960/A 960M.

12. Dimensions

12.1 Butt-welding fittings and butt-welding short radius elbows and returns purchased in accordance with this specification shall conform to the dimensions and tolerances given in the latest revision of ASME B16.9. Steel socket-welding and threaded fittings purchased in accordance with this specification shall conform to the sizes, shapes, dimensions, and tolerances specified in the latest revision of ASME B16.11, MSS-SP-79, or MSS-SP-83.

12.2 Fittings of size or shape differing from these standards, but meeting all other requirements of this specification may be furnished in accordance with Supplementary Requirement S58 in Specification A 960/A 960M.

13. Surface Quality

13.1 See Specification A 960/A 960M.

14. Repair by Welding

14.1 See Specification A 960/A 960M.

15. Inspection

15.1 See Specification A 960/A 960M.

15.2 Other tests, when required by agreement, shall be made from material of the lots covered in the order.

16. Rejection and Rehearing

16.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly in writing. In case of dissatisfaction with the results of the tests, the producer or supplier may make claim for a rehearing.

16.2 Fittings that develop defects in shopworking or application operations may be rejected. Upon rejection, the manufacturer shall be notified promptly in writing.

17. Certification

17.1 Test reports are required for all fittings covered by this specification. Each test report shall include the following information:

17.1.1 Chemical analysis results, Section 8 (Table 1). When the amount of an element is less than 0.02 %, the analysis for that element may be reported as "<0.02 %."

17.1.2 Tensile property results, Section 9 (Table 2), report the yield strength and ultimate strength in ksi [MPa] and elongation in percent,

17.1.3 Hardness acceptable in accordance with Section 10,

17.1.4 Type heat treatment, if any, Section 7,

17.1.5 Seamless or welded,

17.1.6 Starting material, specifically pipe, plate, etc.,

17.1.7 Statement regarding radiographic or ultrasonic examination, 6.2,

17.1.8 Any supplemental testing required by the purchase order,

17.1.9 Statement that the fitting was manufactured, sampled, tested, and inspected in accordance with the specification, and was found to meet the requirements, and

17.1.10 The specification number, year of issue, revision letter (if any), grade and class of the fittings.

18. Product Marking

18.1 All fittings shall have the prescribed information stamped or otherwise suitably marked on each fitting in accordance with the Standard Marking System for Valves, Fittings, Flanges and Unions (MSS-SP-25, latest edition).

18.2 The prescribed information for butt-welding fittings shall be: The manufacturer's name or trademark (see Note 2), schedule number or nominal wall thickness designation, size, fitting designation in accordance with Annex A1 and the heat number or manufacturer's heat identification.

NOTE 2—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component complies with this specification.

18.3 The prescribed information for threaded or socket-welding fittings shall be: The manufacturer's name or trademark (see Note 2), pressure class or schedule number and fitting designation in accordance with Annex A1, and the heat number or the manufacturer's heat identification.

18.4 Specification number, year of issue and revision letter are not required to be marked on fittings.

18.5 *Bar Coding*—In addition to the requirements in 18.1, 18.2, 18.3 and 18.4, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small fittings, the bar code may be applied to the box or a substantially applied tag.

19. Keywords

19.1 pipe fittings—steel; piping applications; pressure containing parts; pressure vessel service; temperature service applications—elevated

SUPPLEMENTARY REQUIREMENTS

These requirements shall not be considered unless specified in the order, in which event, the supplementary requirements specified shall be made at the place of manufacture, unless otherwise agreed upon, at the purchaser's expense. The test specified shall be witnessed by the purchaser's inspector before shipment of material, if so specified in the order.

S1. Alternative Heat Treatment—Grade WP91

S1.1 Grade WP91 shall be normalized in accordance with 7.3.4 and tempered at a temperature, to be specified by the purchaser, less than 1350 °F [730 °C]. It shall be the purchaser's responsibility to subsequently temper the entire fitting in the temperature range of 1350 °F [730 °C] to 1470 °F [800 °C] as a final heat treatment. All mechanical tests shall be made on material heat treated in accordance with 7.3.4. The certification shall reference this supplementary requirement indicating the actual tempering temperature applied. The notation "S1'' shall be included with the required marking of the fitting.

S2. Restricted Vanadium Content

S2.1 The vanadium content of the fittings shall not exceed 0.03 %.

S3. Carbon Equivalent

S3.1 For grades WPB and WPC, the maximum carbon equivalent (C.E.), based on heat analysis and the following formula, shall be 0.50.

$$C.E. = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

S3.2 A lower maximum carbon equivalent may be agreed upon between the purchaser and the supplier.

S3.3 The C.E. shall be reported on the test report.

ANNEX

(Mandatory Information)

A1. FITTING DESIGNATION FOR MARKING PURPOSES

TABLE A1.1 Fitting Designation for Marking Purposes

Grade	Class	Construction	Mandatory Marking
WPB		W (Welded construction)	WPBW[A]
		S (Seamless construction)	WPB
WPC		W (Welded construction)	WPCW[A]
		S (Seamless construction)	WPC
WP1		W (Welded construction)	WP1W[A]
		S (Seamless construction)	WP1
WP12	CL1	W (Welded construction)	WP12 CL1W[A]
		S (Seamless construction)	WP12 CL1
	CL2	W (Welded construction)	WP12 CL2W[A]
		S (Seamless construction)	WP12 CL2
WP11	CL1	W (Welded construction)	WP11 CL1W[A]
		S (Seamless construction)	WP11 CL1
	CL2	W (Welded construction)	WP11 CL2W[A]
		S (Seamless construction)	WP11 CL2
	CL3	W (Welded construction)	WP11 CL3W[A]
		S (Seamless construction)	WP11 CL3
WP22	CL1	W (Welded construction)	WP22 CL1W[A]
		S (Seamless construction)	WP22 CL1
	CL3	W (Welded construction)	WP22 CL3W[A]
		S (Seamless construction)	WP22 CL3
WP5	CL1	W (Welded construction)	WP5 CL1W[A]
		S (Seamless construction)	WP5 CL1
	CL3	W (Welded construction)	WP5 CL3 W[A]
		S (Seamless construction)	WP5 CL3
WP9	CL1	W (Welded construction)	WP9 CL1 W[A]
		S (Seamless construction)	WP9 CL1
	CL3	W (Welded construction)	WP9 CL3 W[A]
		S (Seamless construction)	WP9 CL3
WPR		W (Welded construction)	WPR W[A]
		S (Seamless construction)	WPR
WP91		W (Welded construction)	WP91W[A]
		S (Seamless construction)	WP91

[A] Add "U" to marking if welds are ultrasonic inspected in lieu of radiography.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 234/A 234M – 06a, that may impact the use of this specification. (Approved March 1, 2007)

(*1*) Added MSS-SP-83 to 1.1 and 12.1.
(*2*) Revised 2.6 to delete the year date of SNT-TC-1A.
(*3*) Revised 17.1.9.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 234/A 234M – 06, that may impact the use of this specification. (Approved September 1, 2006)

(*1*) Reduced Al maximum and added maximums for Ti and Zr for Grades WP91 and WP911 in Table 1 and applied maximums of these elements to both heat and product analyses.

(*2*) Revised tempering heat treatment in S1 from a minimum to a range.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 234/A 234M – 05a, that may impact the use of this specification. (Approved May 1, 2006)

(*1*) Revised 17.1.
(*2*) Added 17.1.9 to add mandatory reporting requirements.
(*3*) Reworded and removed 17.2 and replaced with 17.1.10.

Designation: A 214/A 214M – 96 (Reapproved 2005)

Standard Specification for Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes[1]

This standard is issued under the fixed designation A 214/A 214M; 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

1.1 This specification[2] covers minimum-wall-thickness, electric-resistance-welded, carbon steel tubes to be used for heat exchangers, condensers, and similar heat-transfer apparatus.

1.2 The tubing sizes usually furnished to this specification are to 3 in. [76.2 mm] in outside diameter, inclusive. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 The purchaser shall specify in the order the outside diameter and minimum wall thickness. The inside diameter shall not be specified.

1.5 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:* [3]

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

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 (electric-resistance-welded tubes),

3.1.3 Size (outside diameter and minimum wall thickness),

3.1.4 Length (specific or random),

3.1.5 Optional requirements (Section 8 and 10.5),

3.1.6 Test report required (see Certification Section of Specification A 450/A 450M),

3.1.7 Specification designation, and

3.1.8 Special requirements.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

5. Manufacture

5.1 Tubes shall be made by electric-resistance welding.

6. Heat Treatment

6.1 After welding, all tubes shall be heat treated at a temperature of 1650°F [900°C] or higher and followed by cooling in air or in the cooling chamber of a controlled atmosphere furnace. Cold drawn tubes shall be heat treated after the final cold-draw pass at a temperature of 1200°F [650°C] or higher.

7. Chemical Composition

7.1 The steel shall conform to the following requirements as to chemical composition:

Carbon, max %	0.18

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Oct. 1, 2005. Published October 2005. Originally approved in 1939. Last previous edition approved in 2001 as A 214/A 214M – 96 (2001).

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-214 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.

Manganese, %	0.27 to 0.63
Phosphorus, max, %	0.035
Sulfur, max, %	0.035

7.2 Supplying an alloy grade of steel that specifically requires the addition of any element other than those listed in 7.1 is not permitted.

8. Product Analysis

8.1 When requested on the purchase order, a product analysis shall be made by the supplier from 1 tube per 250 pieces; when tubes are identified by heat, one tube per heat shall be analyzed. 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 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 (Note 1) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 1—A lot consists of 250 tubes.

9. Hardness Requirements

9.1 The tubes shall have a hardness number not exceeding 72 HRB.

10. Mechanical Tests Required

10.1 *Flattening Test*—One flattening test shall be made on specimens from each of two tubes from each lot (Note 1) or fraction thereof.

10.2 *Flange Test*—One flange test shall be made on specimens from each of two tubes from each lot (Note 1) or fraction thereof.

10.3 *Reverse Flattening Test*—One reverse flattening test shall be made on a specimen from each 1500 ft [450 m] of finished tubing.

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

10.5 *Hydrostatic or Nondestructive Electric Test*—Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

11. Surface Condition

11.1 The finished tubes shall be free of scale. A slight amount of oxidation shall not be considered as scale.

12. Product Marking

12.1 In addition to the marking prescribed in Specification A 450/A 450M, the letters "ERW" shall be legibly stenciled on each tube, or marked on a tag attached to the bundle or box in which the tubes are shipped.

12.2 The manufacturer's name or symbol may be placed permanently on each tube by rolling or light stamping before normalizing. If a single stamp is placed on the tube by hand, this mark should not be less than 8 in. [200 mm] from one end of the tube.

12.3 *Bar Coding*—In addition to the requirements in 12.1 and 12.2 bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes[1]

This standard is issued under the fixed designation A 213/A 213M; 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*

1.1 This specification[2] covers seamless ferritic and austenitic steel boiler, superheater, and heat-exchanger tubes, designated Grades T5, TP304, etc. These steels are listed in Tables 1 and 2.

1.2 Grades containing the letter, H, in their designation, have requirements different from those of similar grades not containing the letter, H. These different requirements provide higher creep-rupture strength than normally achievable in similar grades without these different requirements.

1.3 The tubing sizes and thicknesses usually furnished to this specification are ⅛ in. [3.2 mm] in inside diameter to 5 in. [127 mm] in outside diameter and 0.015 to 0.500 in. [0.4 to 12.7 mm], inclusive, in minimum wall thickness or, if specified in the order, average wall thickness. Tubing having other diameters may be furnished, provided such tubes comply with all other requirements of this specification.

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.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

E 112 Test Methods for Determining Average Grain Size

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminology A 941.

4. Ordering Information

4.1 It shall be the responsibility of the purchaser to specify all requirements that are necessary for products under this specification. Such requirements to be considered include, but are not limited to, the following:

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of material (seamless tubes),

4.1.3 Grade (Tables 1 and 2),

4.1.4 Condition (hot finished or cold finished),

4.1.5 Controlled structural characteristics (see 6.3),

4.1.6 Size (outside diameter and minimum wall thickness, unless average wall thickness is specified),

4.1.7 Length (specific or random),

4.1.8 Hydrostatic Test or Nondestructive Electric Test (see 10.1),

4.1.9 Specification designation and year of issue,

4.1.10 Increased sulfur (for machinability, see Note B, Table 1, and 15.3), and

4.1.11 Special requirements and any supplementary requirements selected.

5. General Requirements

5.1 Product furnished to this specification shall conform to the requirements of Specification A 1016/A 1016M, including any supplementary requirements that are indicated in the

[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-213 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.

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

TABLE 1 Chemical Composition Limits, %[A], for Low Alloy Steel

Grade	UNS Designation	Composition, %														
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Vanadium	Boron	Niobium	Nitrogen	Aluminum	Tungsten	Other Elements
T2	K11547	0.10–0.20	0.30–0.61	0.025	0.025[B]	0.10–0.30	...	0.50–0.81	0.44–0.65	...	...	...	...	...	...	...
T5	K41545	0.15	0.30–0.60	0.025	0.025	0.50	...	4.00–6.00	0.45–0.65	...	...	...	...	...	...	...
T5b	K51545	0.15	0.30–0.60	0.025	0.025	1.00–2.00	...	4.00–6.00	0.45–0.65	...	...	...	...	...	...	...
T5c	K41245	0.12	0.30–0.60	0.025	0.025	0.50	...	4.00–6.00	0.45–0.65	...	...	...	...	...	...	Ti 4xC–0.70
T9	K90941	0.15	0.30–0.60	0.025	0.025	0.25–1.00	...	8.00–10.00	0.90–1.10	...	...	...	...	...	...	...
T11	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	...	...	...	...	...	...	...
T12	K11562	0.05–0.15	0.30–0.61	0.025	0.025[B]	0.50	...	0.80–1.25	0.44–0.65	...	...	...	...	...	...	...
T17	K12047	0.15–0.25	0.30–0.61	0.025	0.025	0.15–0.35	...	0.80–1.25	...	0.15	...	...	...	...	...	...
T21	K31545	0.05–0.15	0.30–0.60	0.025	0.025	0.50–1.00	...	2.65–3.35	0.80–1.06	...	...	...	...	...	...	...
T22	K21590	0.05–0.15	0.30–0.60	0.025	0.025	0.50	...	1.90–2.60	0.87–1.13	...	...	...	...	...	...	...
T23	K40712	0.04–0.10	0.10–0.60	0.030	0.010	0.50	...	1.90–2.60	0.05–0.30	0.20–0.30	0.0005–0.006	0.02–0.08	0.03	0.030	1.45–1.75	...
T24	K30736	0.05–0.10	0.30–0.70	0.020	0.010	0.15–0.45	...	2.20–2.60	0.90–1.10	0.20–0.30	0.0015–0.007	...	0.012	0.02	...	Ti 0.06–0.10
T36	K21001	0.10–0.17	0.80–1.20	0.030	0.025	0.25–0.50	1.00–1.30	0.30	0.25–0.50	0.02	...	0.015–0.045	0.02	0.050	...	Cu 0.50–0.80
T91	K90901	0.07–0.14	0.30–0.60	0.020	0.010	0.20–0.50	0.40	8.0–9.5	0.85–1.05	0.18–0.25	...	0.06–0.10	0.030–0.070	0.02	...	Ti 0.01 Zr 0.01
T92	K92460	0.07–0.13	0.30–0.60	0.020	0.010	0.50	0.40	8.5–9.5	0.30–0.60	0.15–0.25	0.001–0.006	0.04–0.09	0.030–0.070	0.02	1.5–2.00	Ti 0.01 Zr 0.01
T122	K91271	0.07–0.14	0.70	0.020	0.010	0.50	0.50	10.0–11.5	0.25–0.60	0.15–0.30	0.0005–0.005	0.04–0.10	0.040–0.100	0.02	1.50–2.50	Cu 0.30–1.70 Ti 0.01 Zr 0.01
T911	K91061	0.09–0.13	0.30–0.60	0.020	0.010	0.10–0.50	0.40	8.5–9.5	0.90–1.10	0.18–0.25	0.0003–0.006	0.06–0.10	0.040–0.090	0.02	0.90–1.10	Ti 0.01 Zr 0.01

[A] Maximum, unless range or minimum is indicated. Where ellipses (...) appear in this table, there is no requirement, and analysis for the element need not be determined or reported.

[B] It is permissible to order T2 and T12 with a sulfur content of 0.045 max. See 15.3.

purchase order. Failure to comply with the general requirements of Specification A 1016/A 1016M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 1016/A 1016M, this specification shall prevail.

6. Materials and Manufacture

6.1 *Manufacture and Condition*—Tubes shall be made by the seamless process and shall be either hot finished or cold finished, as specified. Grade TP347HFG shall be cold finished.

6.2 *Heat Treatment*:

6.2.1 *Ferritic Alloy and Ferritic Stainless Steels*—The ferritic alloy and ferritic stainless steels shall be reheated for heat treatment in accordance with the requirements of Table 3. Heat treatment shall be carried out separately and in addition to heating for hot forming.

6.2.2 *Austenitic Stainless Steels*—All austenitic tubes shall be furnished in the heat-treated condition, and shall be heat treated in accordance with the requirements of Table 3. Alternatively, immediately after hot forming, while the temperature of the tubes is not less than the minimum solution treatment temperature specified in Table 3, tubes may be individually quenched in water or rapidly cooled by other means (direct quenched).

6.3 If any controlled structural characteristics are required, these shall be so specified in the order as to be a guide as to the most suitable heat treatment.

TABLE 2 Chemical Composition Limits, %[A], for Austenitic and Ferritic Stainless Steel

Grade	UNS Designation	Composition										
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen[B]	Niobium	Titanium	Other Elements
TP201	S20100	0.15	5.5–7.5	0.060	0.030	1.00	16.0–18.0	3.5–5.5	...	0.25	...	...	...
TP202	S20200	0.15	7.5–10.0	0.060	0.030	1.00	17.0–19.0	4.0–6.0	...	.025	...	...	...
XM-19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	0.20–0.40	0.10–0.30	...	V 0.10–0.30
[C]	S21500	0.06–0.15	5.5–7.0	0.045	0.030	0.20–1.00	14.0–16.0	9.0–11.0	0.80–1.20	...	0.75–1.25	...	B 0.003–0.009, V 0.15–0.40
[C]	S25700	0.02	2.00	0.025	0.010	6.5–8.0	8.0–11.5	22.0–25.0	0.50	...	...	...	...
TP304	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...	...
TP304L	S30403	0.035[D]	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	...	...	...	...	...
TP304H	S30409	0.04–0.10	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...	...
[C]	S30432	0.07–0.13	1.00	0.040	0.010	0.30	17.0–19.0	7.5–10.5	...	0.05–0.12	0.30–0.60	...	Al 0.003–0.030, B 0.001–0.010, Cu 2.5–3.5
[C]	S30434	0.07–0.14	2.00	0.040	0.010	1.00	17.5–19.5	9.0–12.0	...	...	0.10–0.40[E]	0.10–0.25[E]	B 0.001–0.004 Cu 2.50–3.50
TP304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	0.10–0.16	...	...	...
TP304LN	S30453	0.035[D]	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	0.10–0.16	...	...	...
[C]	S30615	0.016–0.24	2.00	0.030	0.030	3.2–4.0	17.0–19.5	13.5–16.0	...	...	...	...	Al 0.8–1.5
[C]	S30815	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	...	0.14–0.20	...	...	Ce 0.03–0.08
TP309S	S30908	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	...	...	...	...	...
TP309H	S30909	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	...	...	...	...	...
TP309Cb	S30940	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	...	...	10xC–1.10	...	...
TP309HCb	S30941	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	...	...	10xC-1.10	...	...
...	S30942	0.03–0.10	2.00	0.040	0.030	1.00	21.0–23.0	14.5–16.5		0.10–0.20	0.50–0.80		B=0.001–0.005
[C]	S31002	0.02	2.00	0.020	0.015	0.15	24.0–26.0	19.0–22.0	0.10	0.10	...	...	...
TP310S	S31008	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...	...	...
TP310H	S31009	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	...	...	...
TP310Cb	S31040	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	10xC-1.10	...	...
TP310HCb	S31041	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	...	10xC-1.10	...	...
TP310HCbN	S31042	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	...	0.15–0.35	0.20–0.60	...	...
TP310MoLN	S31050	0.025	2.00	0.020	0.030	0.40	24.0–26.0	21.0–23.0	2.00–3.00	0.10–0.16	...	...	...
[C]	S31060	0.05–0.10	1.00	0.040	0.030	0.50	22.0–24.0	10.0–12.5	...	0.18–0.25	...	...	Ce + La 0.025–0.070 B 0.001–0.010
[C]	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	0.18–.022	...	...	Cu 0.50–1.00
[C]	S31272	0.08–0.12	1.50–2.00	0.030	0.015	0.30–0.70	14.0–16.0	14.0–16.0	1.00–1.40	...	...	0.30–0.60	B 0.004–0.008
[C]	S31277	0.020	3.00	0.030	0.010	0.50	20.5–23.0	26.0–28.0	6.5–8.0	0.30–0.40	...	...	Cu 0.50–1.50
TP316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	...
TP316L	S31603	0.035[D]	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	...
TP316H	S31609	0.04–0.10	2.00	0.045	0.030	1.00	16.0–18.0	11.0–14.0	2.00–3.00	...	...	...	...
TP316Ti	S31635	0.08	2.00	0.045	0.030	0.75	16.0–18.0	10.0–14.0	2.00–3.00	0.10	...	5X (C + N)–0.70	...
TP316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	0.10–0.16	...	...	...
TP316LN	S31653	0.035[D]	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	0.10–0.16	...	...	...
TP317	S31700	0.08	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...	...	...

TABLE 2 *Continued*

Grade	UNS Designation	Composition											
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen[B]	Niobium	Titanium	Other Elements
TP317L	S31703	0.035	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	3.0–4.0	...	...	...	...
TP317LM	S31725	0.03	2.00	0.045	0.030	1.00	18.0–20.0	13.5–17.5	4.0–5.0	0.20	...	...	Cu 0.75
TP317LMN	S31726	0.03	2.00	0.045	0.030	1.00	17.0–20.0	13.5–17.5	4.0–5.0	0.10–0.20	...	...	Cu 0.75
[C]	S32050	0.030	1.50	0.035	0.020	1.00	22.0–24.0	20.0–23.0	6.0–6.8	0.21–0.32	...	...	Cu 0.40
TP321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	5(C + N)–0.70	...
TP321H	S32109	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	...	4(C + N)–0.70	...
[C]	S32615	0.07	2.00	0.045	0.030	4.8–6.0	16.5–19.5	19.0–22.0	0.30–1.50	...	...	...	Cu 1.50–2.50
[C]	S33228	0.04–0.08	1.00	0.020	0.015	0.30	26.0–28.0	31.0–33.0	...	...	0.60–1.00	...	Ce 0.05–0.10, Al 0.025
[C]	S34565	0.030	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	4.0–5.0	0.40–0.60	0.10	...	...
TP347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–20.0	9.0–13.0	...	...	10xC–1.10	...	...
TP347H	S34709	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	8xC–1.10	...	...
TP347HFG	S34710	0.06–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	8xC–1.10	...	...
TP347LN	S34751	0.005–0.020	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	0.06–0.10	0.20–0.50[F]	...	...
TP348	S34800	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	[G]	...	Co 0.20, Ta 0.10
TP348H	S34809	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	...	...	[H]	...	Co 0.20, Ta 0.10
...	S35045	0.06–0.10	1.50	0.045	0.015	1.00	25.0–29.0	32.0–37.0	...	...	...	0.15–0.60	Al 0.15–0.60 Cu 0.75
XM-15	S38100	0.08	2.00	0.030	0.030	1.50–2.50	17.0–19.0	17.5–18.5	...	...	...	...	...
...	S38815	0.030	2.00	0.040	0.020	5.5–6.5	13.0–15.0	15.0–17.0	0.75–1.50	...	...	...	Cu 0.75–1.50 Al 0.30
TP444	S44400	0.03	1.00	0.040	0.030	1.00	17.5–19.5	[I]	1.75–2.50	0.035	...	[J]	...

[A] Maximum, unless a range or minimum is indicated. Where ellipses (...) appear in this table, there is no minimum and analysis for the element need not be determined or reported.
[B] The method of analysis for Nitrogen shall be a matter of agreement between the purchaser and the producer.
[C] For these alloys, there is no common grade designation. The UNS number uniquely identifies these alloys.
[D] For small diameter or thin walls, or both, where many drawing passes are required, a carbon maximum of 0.040% is necessary in Grades TP304L, TP304LN, TP316L, and TP316LN.
[E] Grade S30434 shall have (Ti + ½ Nb) of not less than 2 times and not more than 4 times the carbon content.
[F] Grade TP347LN shall have an Nb content of not less than 15 times the carbon content.
[G] Grade TP348 shall have an Nb + Ta content of not less than 10 times the carbon content and not more than 1.10%.
[H] Grade TP348H shall have an Nb + Ta content of not less than 8 times the carbon content and not more than 1.10%.
[I] Grade TP444 shall have Ni + Cu = 1.00 max.
[J] Grade TP444 shall have Ti + Nb = 0.20 + 4(C + N)–0.80.

7. Chemical Composition

7.1 *Composition Requirements*:

7.1.1 The alloy steels shall conform to the chemical requirements given in Table 1.

7.1.2 The stainless steels shall conform to the chemical requirements given in Table 2.

7.2 *Product Analysis*:

7.2.1 An analysis of either one billet or one tube shall be made from each heat. The chemical composition thus determined shall conform to the requirements specified.

7.2.2 If the original test for product analysis fails, retests of two additional billets 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 shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes that do not meet the requirements of the specification shall be rejected.

8. Grain Size

8.1 Grain size shall be as given in Table 3, as determined in accordance with Test Methods E 112.

8.2 Grain size determinations, to demonstrate compliance with 8.1, shall be made on one end of one finished tube from each lot. See 14.1.

9. Mechanical Properties

9.1 *Tensile Requirements*:

9.1.1 The material shall conform to the requirements as to tensile properties given in Table 4.

9.1.2 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 shown in Table 5, the minimum elongation value shall be determined by the following equations. For Grades T23, T24, T91, T92, T122, T911, and S44400: $E = 32t + 10.00$ [$E = 1.25t + 10.00$]. For Grade T36: $E = 32t + 5.0$ [$E = 1.25t + 5.0$]. For all other ferritic alloy grades: $E = 48t + 15.00$ [$E = 1.87t + 15.00$].

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

9.1.3 One tension test shall be made on a specimen from one tube 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. See 14.2.

9.2 *Hardness Requirements*:

9.2.1 The material shall conform to the hardness requirements given in Table 4. See 14.2.

9.2.2 Brinell, Vickers, or Rockwell hardness tests shall be made on specimens from two tubes from each lot. See 14.2.

9.3 *Flattening Test*—One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring test, from each lot. See 14.1.

9.4 *Flaring Test*—One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot. See 14.1.

9.5 Mechanical property requirements do not apply to tubing smaller than 1⁄8 in. [3.2 mm] in inside diameter or thinner than 0.015 in. [0.4 mm] in thickness.

10. Hydrostatic or Nondestructive Electric Test

10.1 Each tube 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.

11. Forming Operations

11.1 Tubes, when inserted in a boiler or tube sheet, shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects. See Note 1.

NOTE 1—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, particularly chromium-containing steels with chromium of 4 % and higher. Therefore, operations that involve heating such steels above their critical temperatures, such as welding, flanging, and hot bending, should be followed by suitable heat treatment.

12. Permissible Variations from the Specified Wall Thickness

12.1 Permissible variations from the specified minimum wall thickness shall be in accordance with Specification A 1016/A 1016M.

12.2 Permissible variations from the specified average wall thickness are ± 10 % of the specified average wall thickness.

13. Surface Condition

13.1 Ferritic alloy cold-finished steel tubes shall be free of scale and suitable for inspection. A slight amount of oxidation is not considered scale.

13.2 Ferritic alloy hot-finished steel tubes shall be free of loose scale and suitable for inspection.

13.3 Stainless steel tubes shall be pickled free of scale. When bright annealing is used, pickling is not necessary.

13.4 Any special finish requirement shall be subject to agreement between the supplier and the purchaser.

14. Sampling

14.1 For flattening, flaring, and grain size requirements, the term lot applies to all tubes, prior to cutting, of the same size (see 4.1.6) that 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 that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace or when the heat-treated condition is obtained directly by quenching after hot forming, 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 6.

14.2 For tensile and hardness test requirements, the term lot applies to all tubes prior to cutting, of the same size (see 4.1.6) that are produced from the same heat of steel. When final heat treatment is in a batch-type furnace, a lot shall include only

TABLE 3 Heat Treatment and Grain Size Requirements[A]

Grade	UNS Number	Heat Treat Type	Austenitizing/ Solutioning Temperature, min or range °F [°C]	Cooling Media	Subcritical Annealing or Tempering Temperature, min or range °F [°C]	ASTM Grain Size No.[B]
			Ferritic Alloy Steels			
T2	K11547	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	…	…
		subcritical anneal	…	…	1200 to 1350 [650 to 730]	…
T5	K41545	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250 [675]	…
T5b	K51545	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250 [675]	…
T5c	K41245	subcritical anneal	…	air or furnace	1350 [730][C]	…
T9	S50400	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250 [675]	…
T11	K11597	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1200 [650]	…
T12	K11562	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	…	…
		subcritical anneal	…	…	1200 to 1350 [650 to 730]	…
T17	K12047	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1200 [650]	…
T21	K31545	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250 [675]	…
T22	K21590	full or isothermal anneal	…	…	…	…
		normalize and temper	…	…	1250 [675]	…
T23	K40712	normalize and temper	1900–1975 [1040–1080]	…	1350–1470 [730–800]	…
T24	K30736	normalize and tempher	1800–1975 [980–1080]	…	1350–1470 [730–800]	…
T36	K21001	normalize and temper	1650 [900]	[D]	1100 [595]	…
T91	K90901	normalize and temper	1900–1975 [1040–1080]	…	1350–1470 [730–800]	…
T92	K92460	normalize and temper	1900–1975 [1040–1080]	…	1350–1470 [730–800]	…
T122	K91261	normalize and temper	1900–1975 [1040–1080]	…	1350–1470 [730–800]	…
T911	K91061	normalize and temper	1900–1975 [1040–1080]	[E]	1365–1435 [740–780]	…
			Austenitic Stainless Steels			
TP201	S20100	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP202	S20200	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
XM-19	S20910	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
…	S21500	solution treatment	1900 [1040][F,G]	water or other rapid cool	…	…
…	S25700	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
…	S30150:	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP304	S30400	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP304L	S30403	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP304H	S30409	solution treatment	1900 [1040]	water or other rapid cool	…	7
…	S30432	solution treatment	2000 [1100][F]	water or other rapid cool	…	…
…	S30434	solution treatment	2120 [1160]	water or other rapid cool	…	…
TP304N	S30451	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP304LN	S30453	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
…	S30615	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
…	S30815	solution treatment	1920 [1050]	water or other rapid cool	…	…
TP309S	S30908	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP309H	S30909	solution treatment	1900 [1040]	water or other rapid cool	…	7
TP309Cb	S30940	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP309HCb	S30941	solution treatment	1900 [1040][H]	water or other rapid cool	…	7
…	S30942	solution treatment	2120 [1160]	water or other rapid cool		6
…	S31002	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP310S	S31008	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP310H	S31009	solution treatment	1900 [1040]	water or other rapid cool	…	7
TP310Cb	S31040	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP310HCb	S31041	solution treatment	1900 [1040][H]	water or other rapid cool	…	7
TP310HCbN	S31042	solution treatment	1900 [1040][F,H]	water or other rapid cool	…	7
…	S31060	solution treatment	1975 [1080]– 2160 [1180][F]	water or other rapid cool	…	7
…	S31254	solution treatment	2100 [1150]	water or other rapid cool	…	…
…	S31272	solution treatment	1920 [1050]	water or other rapid cool	…	…
…	S31277	solution treatment	2050 [1120][F]	water or other rapid cool	…	…

TABLE 3 *Continued*

Grade	UNS Number	Heat Treat Type	Austenitizing/ Solutioning Temperature, min or range °F [°C]	Cooling Media	Subcritical Annealing or Tempering Temperature, min or range °F [°C]	ASTM Grain Size No.[B]
TP316	S31600	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP316L	S31603	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP316H	S31609	solution treatment	1900 [1040]	water or other rapid cool	…	7
TP316Ti	S31635	solution treatment	1900 [1040]	water or other rapid cool	…	…
TP316N	S31651	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP316LN	S31653	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP317	S31700	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP317L	S31703	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
…	S31725	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
…	S32050	solution treatment	2100 [1150][F]	water or other rapid cool	…	…
TP321	S32100	solution treatment	1900 [1040][F,H]	water or other rapid cool	…	…
TP321H	S32109	solution treatment	cold worked: 2000 [1090] hot rolled: 1925 [1050][H]	water or other rapid cool	…	7
…	S32615	solution treatment	1900 [1040][F]	water or other rapid cool	…	3 or finer
…	S32716	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
…	S33228	solution treatment	2050 [1120]	water or other rapid cool	…	…
…	S34565	solution treatment	2050 [1120]– 2140 [1170]	water or other rapid cool	…	…
TP347	S34700	solution treatment	1900 [1040][F,H]	water or other rapid cool	…	…
TP347H	S34709	solution treatment	cold worked: 2000 [1100] hot rolled: 1925 [1050][H]	water or other rapid cool	…	7
TP347HFG	S34710	solution treatment,[I]	2150 [1175][F]	water or other rapid cool	…	7-10
TP347LN	S34751	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
TP348	S34800	solution treatment	1900 [1040][F,H]	water or other rapid cool	…	…
TP348H	S34809	solution treatment	cold worked: 2000 [1100] hot rolled: 1925 [1050][H]	water or other rapid cool	…	7
…	S35045	solution treatment	2000 [1100][F]	still air cool or faster	…	…
XM-15	S38100	solution treatment	1900 [1040][F]	water or other rapid cool	…	…
…	S38815	solution treatment	1950 [1065][F]	water or other rapid cool	…	…
Ferritic Stainless Steels						
TP444	S44400	subcritical anneal	…	…	1400 [760]	…

[A] Where ellipses (…) appear in this table there is no requirement.
[B] ASTM Grain Size No. listed, or coarser, unless otherwise indicated.
[C] Approximately, to achieve properties.
[D] Accelerated air cooling or liquid quenching shall be permitted for Class 2.
[E] Accelerated cooling from the normalizing temperature shall be permitted for section thicknesses greater than 3 in. [75 mm].
[F] Quenched in water or rapidly cooled by other means, at a rate sufficient to prevent re-precipitation of carbides, as demonstrable by the capability of tubes, heat treated by either separate solution annealing or by direct quenching, passing Practices A 262, Practice E. The manufacturer is not required to run the test unless it is specified on the purchase order (see Supplementary Requirement S4). Note that Practices A 262 requires the test to be performed on sensitized specimens in the low-carbon and stabilized types and on specimens representative of the as-shipped condition for other types. In the case of low-carbon types containing 3 % or more molybdenum, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and the purchaser.
[G] A maximum solution treating temperature of 2100 °F [1150 °C] is recommended for UNS S21500.
[H] A solution treating temperature above 1950 °F [1065 °C] may impair resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in the indicated grades. When specified by the purchaser, a lower temperature stabilization or resolution anneal shall be used subsequent to the higher-temperature solution anneal prescribed in this table.
[I] Solution treatment shall be preceded by a softening heat treatment prior to cold-working. The softening temperature shall be at least 90 °F [50 °C] higher than the solution heat treatment temperature, which shall be at 2150 °F [1180 °C] minimum.

those tubes of the same size and the same heat that are heat treated in the same furnace charge. When the final heat treatment is in a continuous furnace, or when the heat-treated condition is obtained directly by quenching after hot forming, 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; or all tubes of the same size and heat, hot formed and quenched in the same production run, except as prescribed in 9.1.3.

15. Product Marking

15.1 In addition to the marking prescribed in Specification A 1016/A 1016M, the marking shall include: the condition, hot finished or cold finished; and the wall designation, minimum wall or average wall.

15.2 For the austenitic stainless steels having a grain size requirement (see Table 3) the marking shall also include the heat number and heat-treatment lot identification.

TABLE 4 Tensile and Hardness Requirements

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %[A,B]	Hardness, Max	
					Brinell/Vickers	Rockwell
Low Alloy Steels:						
T5b	K51545	60[415]	30[205]	30	179 HBW/ 190HV	89 HRB
T9	K90941	60[415]	30[205]	30	179 HBW/ 190HV	89 HRB
T12	K11562	60[415]	32[220]	30	163 HBW/ 170 HV	85 HRB
T23	K40712	74[510]	58[400]	20	220 HBW/ 230 HV	97 HRB
T24	K30736	85[585]	60[415]	20	250 HBW/ 265 HV	25 HRC
T36 Class 1	K21001	90 [620]	64 [440]	15	250 HBW/ 265 HV	25 HRC
T36 Class 2	K21001	95.5 [660]	66.5 [460]	15	250 HBW/ 265 HV	25 HRC
T91	K90901	85[585]	60[415]	20	250 HBW/ 265 HV	25 HRC
T92	K92460	90[620]	64[440]	20	250 HBW/ 265 HV	25 HRC
T122	K91271	90[620]	58[400]	20	250 HBW/ 265 HV	25 HRC
T911	K91061	90[620]	64[440]	20	250 HBW/ 265 HV	25 HRC
All other low alloy grades		60[415]	30[205]	30	163 HB/ 170 HV	85 HRB
Austenitic Stainless Steels:						
TP201	S20100	95[655]	38[260]	35	219 HBW/ 230 HV	95 HRB
TP202	S20200	90[620]	45[310]	35	219 HBW/ 230 HV	95 HRB
XM-19	S20910	100[690]	55[380]	35	250 HBW/ 265 HV	25 HRC
...	S21500	78[540]	33[230]	35	192 HBW/ 200 HV	90 HRB
...	S25700	78[540]	35[240]	50	217 HBW	95 HRB
TP304	S30400	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP304L	S30403	70[485]	25[170]	35	192 HBW/ 200 HV	90 HRB
TP304H	S30409	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
...	S30432	86[590]	34[235]	35	219 HBW/ 230 HV	95 HRB
...	S30434	73 [500]	30 [205]	35	192 HBW/ 200 HV	90 HRB
TP304N	S30451	80[550]	35[240]	35	192 HBW/ 200 HV	90 HRB
TP304LN	S30453	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
...	S30615	90[620]	40[275]	35	192 HBW/ 200 HV	90 HRB
...	S30815	87[600]	45[310]	40	217 HBW	95 HRB
TP309S	S30908	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP309H	S30909	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP309Cb	S30940	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP309HCb	S30941	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
...	S30942	86 [590]	34 [235]	35	219 HBW/ 230 HV	95 HRB
...	S31002	73[500]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP310S	S31008	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB

TABLE 4 *Continued*

Grade	UNS Designation	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %[A,B]	Hardness, Max Brinell/Vickers	Hardness, Max Rockwell
TP310H	S31009	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP310Cb	S31040	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP310HCb	S31041	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP310HCbN	S31042	95[655]	43[295]	30	256 HBW	100 HRB
TP310MoLN	S31050					
T ≤ 0.25 in. [6 mm]		84[580]	39[270]	25	217 HBW	95 HRB
t > 0.25 in. [6 mm]		78[540]	37[255]	25	217 HBW	95 HRB
...	S31060	87[600]	41[280]	40	217 HBW	95 HRB
...	S31254					
T ≤ 0.187 in. [5 mm]		98[675]	45[310]	35	220 HBW/ 230 HV	96 HRB
T > 0.187 in. [5 mm]		95[655]	45[310]	35	220 HBW/ 230 HV	96 HRB
...	S31272	65[450]	29[200]	35	217 HBW	95 HRB
...	S31277	112 [770]	52 [360]	40	241 HBW	100 HRB
TP316	S31600	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP316L	S31603	70[485]	25[170]	35	192 HBW/ 200 HV	90 HRB
TP316H	S31609	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP316Ti	S31635	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP316N	S31651	80[550]	35[240]	35	192 HBW/ 200 HV	90 HRB
TP317	S31700	75[515]	30[205]	34	192 HBW/ 200 HV	90 HRB
TP317L	S31703	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
...	S31725	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
...	S32050	98[675]	48[330]	40	256 HBW	100 HRB
TP321	S32100	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP321H	S32109	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
...	S32615	80[550]	32[220]	25	192 HBW/ 200 HV	90 HRB
...	S32716	80[240]	35[240]	35	192 HBW/ 200 HV	90 HRB
...	S33228	73[500]	27[185]	30	192 HBW/ 200 HV	90 HRB
...	S34565	115[790]	60[415]	35	241 HBW	100 HRB
TP347	S34700	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP347H	S34709	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP347HFG	S34710	80[550]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP347LN	S34751	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP348	S34800	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
TP348H	S34809	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
...	S35045	70[485]	25[170]	35	192 HBW/ 200 HV	90 HRB
XM-15	S38100	75[515]	30[205]	35	192 HBW/ 200 HV	90 HRB
...	S38815	78[540]	37[255]	30	256 HBW	100 HRB
Ferritic Stainless Steels						
TP444	S44400	60[415]	40[275]	20	217 HBW/ 230 HV	96 HRB

[A] When standard round 2 in. or 50 mm gage length or smaller proportionally sized specimens with gage length equal to 4*D* (4 times the diameter) is used, the minimum elongation shall be 22 % for all low alloy grades except T23, T24, T91, T92, T122, and T911; and except for TP444.

[B] For longitudinal strip tests, a deduction from the basic minimum elongation values of 1.00 % for TP444, T23, T24, T91, T92, T122, and T911, and of 1.50 % for all other low alloy grades for each 1⁄32-in. [0.8-mm] decrease in wall thickness below 5⁄16 in. [8 mm] shall be made.

TABLE 5 Computed Minimum Values[A]

Wall Thickness		Elongation in 2 in. or 50 mm, min, %		
in.	mm	S44400, T23, T24, T91, T92, T122, and T911	T ZZ	All Other Ferritic Grades
5⁄16 [0.312]	8	20	15	30
9⁄32 [0.281]	7.2	19	14	29
1⁄4 [0.250]	6.4	18	13	27
7⁄32 [0.219]	5.6	17	12	26
3⁄16 [0.188]	4.8	16	11	24
5⁄32 [0.156]	4	15	10	23
1⁄8 [0.125]	3.2	14	9	21
3⁄32 [0.094]	2.4	13	8	20
1⁄16 [0.062]	1.6	12	7	18
0.062 to 0.035, excl	1.6 to 0.9	12	7	17
0.035 to 0.022, excl	0.9 to 0.6	11	6	17
0.022 to 0.015 incl	0.6 to 0.4	11	6	16

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

15.3 When either T2 or T12 are ordered with higher sulfur contents as permitted by Note B of Table 1, the marking shall include the letter, S, following the grade designation: T2S or T12S.

TABLE 6 Number of Tubes in a Lot Heat Treated by the Continuous Process or by Direct Quench After Hot Forming

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
2 in. [50.8 mm] and over in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

16. Keywords

16.1 alloy steel tubes; austenitic stainless steel; boiler tubes; ferritic stainless steel; heat exchanger tubes; high-temperature applications; seamless steel tubes; steel tubes; superheater tubes; temperature service applications-high

SUPPLEMENTARY REQUIREMENTS

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

S1. Stress-Relieved Annealed Tubes

S1.1 For use in certain corrosives, particularly chlorides where stress corrosion may occur, tubes in Grades TP304L, TP316L, TP321, TP347, and TP348 may be specified in the stress-relieved annealed condition.

S1.2 When stress-relieved tubes are specified, tubes shall be given a heat treatment at 1500 to 1650 °F [815 to 900 °C] after roll straightening. Cooling from this temperature range may be either in air or by slow cooling. No mechanical straightening is permitted after the stress-relief treatment.

S1.3 Straightness of the tubes shall be a matter of negotiation between the purchaser and supplier.

S2. Stabilizing Heat Treatment

S2.1 Subsequent to the solution anneal required in Section 6, Grades TP309HCb, TP310HCb, TP310HCbN, TP321, TP321H, TP347, TP347H, TP348, and TP348H shall be given a stabilization heat treatment at a temperature lower than that used for the initial solution annealing heat treatment. The temperature of stabilization heat treatment shall be at a temperature as agreed upon between the purchaser and vendor.

S3. Unstraightened Tubes

S3.1 When the purchaser specifies tubes unstraightened after final heat treatment (such as coils), the minimum yield strength of Table 4 shall be reduced by 5 ksi [35 MPa].

S3.2 On the certification, and wherever the grade designation for unstraightened tubing appears, it shall be identified with the suffix letter "U" (for example, 304-U, 321-U, etc.).

S4. Intergranular Corrosion Test

S4.1 When specified, material shall pass intergranular corrosion tests conducted by the manufacturer in accordance with Practices A 262, Practice E.

NOTE S4.1—Practice E requires testing on the sensitized condition for low carbon or stabilized grades, and on the as-shipped condition for other grades.

S4.2 A stabilization heat treatment in accordance with Supplementary Requirement S2 may be necessary and is permitted in order to meet this requirement for the grades containing titanium or columbium, particularly in their H versions.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 213/A 213M – 07, that may impact the use of this specification. (Approved September 1, 2007)

(*1*) Added UNS 30942 to Table 2, Table 3, and Table 4.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 213/A 213M – 06a$^{\epsilon 1}$, that may impact the use of this specification. (Approved March 1, 2007)

(*1*) Clarified Ti range for TP315Ti, S31635, inTable 2.

(*2*) Corrected Si max for S33228 in Table 2.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 213/A 213M – 06, that may impact the use of this specification. (Approved May 1, 2006)

(*1*) Reduced Cr maximum for Grade 122 in Table 1.

(*2*) Reduced Al maximum and added maximums for Ti and Zr for Grades T91, T92, T122, and T911 in Table 1.

(*3*) Revised Ni maximum for Grades TP347H, TP347HFG, TP348, and TP348H in Table 2.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 213/A 213M – 05c, that may impact the use of this specification. (Approved March 1, 2006)

(*1*) Revised Tables 2-4 to add new Grade S30434.

Designation: A 210/A 210M – 02

Standard Specification for Seamless Medium-Carbon Steel Boiler and Superheater Tubes[1]

This standard is issued under the fixed designation A 210/A 210M; 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 minimum-wall-thickness, seamless medium-carbon steel, boiler tubes and boiler flues, including safe ends (see Note 1), arch and stay tubes, and superheater tubes.

NOTE 1—This type is not suitable for safe ending by forge welding.

1.2 The tubing sizes and thicknesses usually furnished to this specification are ½ in. to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.500 in. [0.9 to 12.7 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

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.

2. Referenced Documents

2.1 *ASTM Standards:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes[3]

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 tubes),

3.1.3 Grade,

3.1.4 Manufacture (hot-finished or cold-finished),

3.1.5 Size (outside diameter and minimum wall thickness),

3.1.6 Length (specific or random),

3.1.7 Optional requirements (Sections 7 and 10),

3.1.8 Test report required, (see Certification Section of Specification A 450/A 450M),

3.1.9 Specification designation, and

3.1.10 Special requirements.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

5. Manufacture

5.1 *Steelmaking Practice*—The steel shall be killed.

5.2 The tubes shall be made by the seamless process and shall be either hot-finished or cold-finished, as specified.

6. Heat Treatment

6.1 Hot-finished tubes need not be heat treated. Cold-finished tubes shall be given a subcritical anneal, a full anneal, or a normalizing heat treatment after the final cold finishing process.

7. Surface Condition

7.1 If pickling or shot blasting or both are required, this shall be specifically stated in the order.

8. Chemical Composition

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

8.2 When a grade is 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.

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Sept. 10, 2002. Published November 2002. Originally published as A 210 – 38 T. Last previous edition A 210/A 210M – 96 (2001).

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-210 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

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

TABLE 1 Chemical Requirements

Element	Composition, %	
	Grade A-1	Grade C
Carbon[A], max	0.27	0.35
Manganese	0.93 max	0.29–1.06
Phosphorus, max	0.035	0.035
Sulfur, max	0.035	0.035
Silicon, min	0.10	0.10

[A] For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted up to a maximum of 1.35 %.

9. Product Analysis

9.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube or billet per heat. The chemical composition thus determined shall conform to the requirements specified.

9.2 If the original test for product analysis fails, retests of two additional billets 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 (see Note 2) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 2—For flattening and flaring 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.

NOTE 3—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.

10.2 Table 4 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 shown above, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00 \; [E = 1.87t + 15.00]$$

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

TABLE 2 Number of Tubes in a Lot Heat Treated by the Continuous Process

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
2 in. (50.8 mm) and over in outside diameter and under 0.200 in. (5.1 mm) in wall thickness	not more than 75 tubes
Less than 2 in. (50.8 mm) but over 1 in. (25.4 mm) in outside diameter	not more than 75 tubes
1 in. (25.4 mm) or less in outside diameter	not more than 125 tubes

TABLE 3 Tensile Requirements

	Grade A-1	Grade C
Tensile strength, min, ksi [MPa]	60 [415]	70 [485]
Yield strength, min, ksi [MPa]	37 [255]	40 [275]
Elongation in 2 in. or 50 mm, min, %	30	30
For longitudinal strip tests, a deduction shall be made for each 1⁄32-in. [0.8-mm] decrease in wall thickness under 5⁄16in. [8 mm] from the basic minimum elongation of the following percentage points	1.50 [A]	1.50 [A]
When standard round 2-in. or 50-mm gage length or smaller proportionally sized specimen with the gage length equal to 4*D* (four times the diameter) is used	22	20

[A] See Table 4 for the computed minimum values.

TABLE 4 Computed Minimum Elongation Values

Wall Thickness, in. [mm]	Elongation in 2 in. or 50 mm, min, % [A]
5⁄16 (0.312) [8]	30
9⁄32 (0.281) [7.2]	28
1⁄4 (0.250) [6.4]	27
7⁄32 (0.219) [5.6]	26
3⁄16 (0.188) [4.8]	24
5⁄32 (0.156) [4]	22
1⁄8 (0.125) [3.2]	21
3⁄32 (0.094) [2.4]	20
1⁄16 (0.062) [1.6]	18
0.062 to 0.035 [1.6 to 0.9], excl	17
0.035 to 0.022 [0.9 to 0.6], excl	16
0.022 to 0.015 [0.6 to 0.4], incl	16

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

11. Hardness Requirements

11.1 The tubes shall have a hardness not exceeding the following: 79 HRB or 143 HB for Grade A-1, 89 HRB or 179 HB for Grade C.

12. Mechanical Tests Required

12.1 *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 (see Note 3).

12.2 *Flattening Test*—One flattening test shall be made on specimens from each end of one finished tube from each lot (see Note 2), but not the one used for the flaring test. Tears or breaks occurring at the 12 or 6 o'clock positions on Grade C tubing with sizes of 2.375 in. [60.3 mm] in outside diameter and smaller shall not be considered a basis for rejection.

12.3 *Flaring Test*—One flaring test shall be made on specimens from each end of the one finished tube from each lot (see Note 2), but not the one used for the flattening test.

12.4 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (see Note 3).

12.5 *Hydrostatic or Nondestructive Electric Test*—Each tube shall be subjected to the hydrostatic, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser.

13. Forming Operations

13.1 When inserted in the boiler, tubes shall stand expanding and beading without showing cracks or flaws. When properly manipulated, superheater tubes shall stand all forging, welding, and bending operations necessary for application without developing defects.

14. Product Marking

14.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall indicate whether the tube is hot-finished or cold-finished.

14.2 *Bar Coding*—In addition to the requirements in 14.1 bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

15. Keywords

15.1 boiler tubes; carbon; seamless steel tube; steel tube; superheater tubes

SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification that have been incorporated since the last edition, A 210/A 210M – 96 (2001), as follows:

(1) Paragraph 1.4 was deleted and the subsequent subsection was renumbered.

(2) Paragraph 2.1 was revised to delete reference to Specification A 520.

Designation: A 209/A 209M – 03 (Reapproved 2007)

Standard Specification for Seamless Carbon-Molybdenum Alloy-Steel Boiler and Superheater Tubes[1]

This standard is issued under the fixed designation A 209/A 209M; 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 several grades of minimum-wall-thickness, seamless, carbon-molybdenum alloy-steel, boiler and superheater tubes.

1.2 This specification covers tubes ½ to 5 in. [12.7 to 127 mm] inclusive, in outside diameter and 0.035 to 0.500 in. [0.9 to 12.7 mm], inclusive, in minimum wall thickness.

1.3 An optional supplementary requirement is provided and, when desired, shall be so stated in the order.

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.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 1016/A 1016M Specification for General Requirements for Ferritic Alloy Steel, Austenitic Alloy Steel, and Stainless Steel Tubes

3. General Requirements

3.1 Product furnished under this specification shall conform to the requirements of Specification A 1016/A 1016M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 1016/A 1016M constitutes nonconformance with this specification. In case of conflict with the requirements of this specification and Specification A 1016/A 1016M, this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed.

4.2 The tubes shall be made by the seamless process and shall be either hot-finished or cold-finished, as specified.

4.3 *Heat Treatment*—Hot-finished tubes shall be heat treated at a temperature of 1200 °F [650 °C] or higher. Cold-finished tubes shall, after the final cold finishing, be heat treated at a temperature of 1200 °F [650 °C] or higher, or tubing may be furnished in the full-annealed, isothermal annealed, or normalized and tempered condition. If furnished in the normalized and tempered condition, the minimum tempering temperature shall be 1200 °F [650 °C].

5. Chemical Composition

5.1 The steel shall conform to the requirements given in Table 1.

TABLE 1 Chemical Composition Requirements

Element	Composition, %		
	Grade T1	Grade T1a	Grade T1b
Carbon	0.10–0.20	0.15–0.25	0.14 max
Manganese	0.30–0.80	0.30–0.80	0.30–0.80
Phosphorus, max	0.025	0.025	0.025
Sulfur, max	0.025	0.025	0.025
Silicon	0.10–0.50	0.10–0.50	0.10–0.50
Molybdenum	0.44–0.65	0.44–0.65	0.44–0.65

5.2 *Product Analysis*

5.2.1 An analysis shall be made by the manufacturer of one billet or one tube from each heat. The chemical composition thus determined, shall conform to the requirements given in Table 1.

5.2.2 If the original test for product analysis fails, retests of two additional billets 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 (See 7.1) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes that do not meet the requirements of the specification shall be rejected.

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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.

Current edition approved Sept. 1, 2007. Published October 2007. Originally approved in 1938. Last previous edition approved in 2003 as A 209/A 209M – 03.

[2] For ASME Boiler and Pressure Vessel Code application see related Specification SA-209 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.

6. Mechanical Properties

6.1 *Tensile Requirements*

6.1.1 The material shall conform to the requirements given in Table 2.

6.1.2 Table 3 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 shown above, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00\ [E = 1.87t + 15.00] \tag{1}$$

where:

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

6.2 *Hardness Requirements*—The tubes shall have a hardness not exceeding the values given in Table 4.

6.3 *Number of Tests*

6.3.1 *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 (See 7.2)

6.3.2 *Flattening Test*—One flattening test shall be made on specimens from each end of one finished tube, not the one used for the flaring test, from each lot (See 7.1)

6.3.3 *Flaring Test*—One flaring test shall be made on specimens from each end of one finished tube, not the one used for the flattening test, from each lot (See 7.1)

6.3.4 *Hardness Test*—Brinell or Rockwell hardness tests shall be made on specimens from two tubes from each lot (See 7.2)

7. Sampling

7.1 *Flattening, Flaring, and Product Analysis*—For flattening, flaring, and product analysis requirements, the term *lot* applies to all tubes prior to cutting of the same nominal size and wall thickness that 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 that 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 given in Table 5.

TABLE 2 Tensile Requirements

	Grade T1	Grade T1b	Grade T1a
Tensile strength, min, ksi [MPa]	55 [380]	53 [365]	60 [415]
Yield strength, min, ksi [MPa]	30 [205]	28 [195]	32 [220]
Elongation in 2 in. or 50 mm, min, %	30	30	30
For longitudinal strip tests a deduction shall be made 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	1.50[A]	1.50[A]	1.50[A]
When standard round 2-in. or 50-mm gage length or smaller proportionally sized specimen with the gage length equal to 4*D* (four times the diameter) is used	22	22	22

[A] Table 3 gives the computed minimum values.

TABLE 3 Computed Minimum Values

Wall Thickness, in.	Wall Thickness, mm	Elongation in 2 in. or 50 mm, min, %[A]
5 / 16 (0.312)	8	30
9 / 32 (0.281)	7.2	29
1 / 4 (0.250)	6.4	27
7 / 32 (0.219)	5.6	26
3 / 16 (0.188)	4.8	24
5 / 32 (0.156)	4	22
1 / 8 (0.125)	3.2	21
3 / 32 (0.094)	2.4	20
1 / 16 (0.062)	1.6	18

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

TABLE 4 Hardness Requirements

	Brinell Hardness Number (Tubes 0.200 in. [5.1 mm] and over in Wall Thickness), HBW	Rockwell Hardness Number (Tubes less than 0.200 in. [5.1 mm] in Wall Thickness), HRB
Grade T 1	146	80
Grade T 1a	153	81
Grade T 1b	137	77

TABLE 5 Number of Tubes in a Lot Heat Treated by the Continuous Process

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
2 in. [50.8 mm] and over in outside diameter and under 0.200 in. [5.1 mm] in wall thickness	not more than 75 tubes
Less than 2 in. [50.8 mm] but over 1 in. [25.4 mm] in outside diameter	not more than 75 tubes
1 in. [25.4 mm] or less in outside diameter	not more than 125 tubes

7.2 *Tension and Hardness Tests*—For tension and hardness tests, the term *lot* applies to all tubes prior to cutting, of the same nominal diameter and wall thickness that 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 that 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.

8. Forming Operations

8.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects.

9. Product Marking

9.1 In addition to the marking prescribed in Specification A 1016/A 1016M, the marking shall include whether the tube is hot-finished or cold-finished.

10. Keywords

10.1 boiler tubes; carbon-molybdenum; seamless steel tube; steel tube; superheater tubes

SUPPLEMENTARY REQUIREMENTS

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

S1. Surface Condition

S1.1 If pickling or shot blasting, or both, are required, this shall be specifically stated in the order. Details of this supplemental requirement shall be agreed upon between the manufacturer and the purchaser.

Endorsed by
Manufacturers Standardization Society
of the Valve and Fittings Industry
Used in USNRC-RDT Standards

Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both[1]

This standard is issued under the fixed designation A 194/A 194M; 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*

1.1 This specification[2] covers a variety of carbon, alloy, and martensitic stainless steel nuts in the size range ¼ through 4 in. and metric M6 through M100 nominal. It also covers austenitic stainless steel nuts in the size range ¼ in. and M6 nominal and above. These nuts are intended for high-pressure or high-temperature service, or both. Grade substitutions without the purchaser's permission are not allowed.

1.2 Bars from which the nuts are made shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be solution annealed or annealed and strain-hardened. When annealed and strain hardened austenitic stainless steel is ordered in accordance with Supplementary Requirement S1, the purchaser should take special care to ensure that 8.2.2, Supplementary Requirement S1, and Appendix X1 are thoroughly understood.

1.3 Supplementary requirements (S1 through S8) of an optional nature are provided. These shall apply only when specified in the inquiry, contract, and order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable" M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 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.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 276 Specification for Stainless Steel Bars and Shapes
A 320/A 320M Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service
A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
B 696 Specification for Coatings of Cadmium Mechanically Deposited
B 766 Specification for Electrodeposited Coatings of Cadmium
E 112 Test Methods for Determining Average Grain Size
F 1940 Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners
F 1941 Specification for Electrodeposited Coatings on Threaded Fasteners (Unified Inch Screw Threads (UN/UNR))

2.2 *American National Standards:*[4]

B 1.1 Unified Screw Threads
B 1.2 Gages and Gaging for Unified Inch Screw Threads
B 1.13M Metric Screw Threads
B 18.2.2 Square and Hex Nuts
B 18.2.4.6M Metric Heavy Hex Nuts

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved March 1, 2007. Published April 2007. Originally approved in 1936. Last previous edition approved in 2007 as A 194/A 194M–07.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-194 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 National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

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

3.1.1 *Austenitic Grades*—All grades with a prefix of “8” or “9”.

3.1.2 *Ferritic Grades*—Grades 1, 2, 2H, 2HM, 3, 4, 6, 6F, 7, 7M, and 16.

3.1.3 *Lot*—Unless otherwise specified (see Discussion below), a lot is the quantity of nuts of a single nominal size and grade produced by the same manufacturing process.

3.1.3.1 *Discussion*—When Supplementary Requirement S5 is invoked on the purchase order, the following definitions of a lot shall apply:

3.1.3.2 *For Grade 8 Nuts*—The quantity of all the nuts of a single nominal diameter and grade made from the same heat of steel and made by the same manufacturing process.

3.1.3.3 *For All Other Grade Nuts*— (see 8.2 and 8.1.2.1)—All the nuts of a single nominal diameter and grade made from the same heat number and heat treated in the same batch if batch-type heat treating equipment is used or heat treated in the same continuous run of not more than 8 h under the same conditions if continuous-type heat treating equipment is used.

3.1.4 *Type*

3.1.4.1 *For Grade 8 Nuts*—Variations within the grade designated by a letter and differentiated by chemistry and by manufacturing process.

3.1.4.2 *For Grade 6 Nuts*—Variations within the grade designated by the letter F as differentiated by chemical additions made for machineability.

3.1.5 *Series*—The dimensional relationship and geometry of the nuts as described in ANSI B 18.2.2 or B 18.2.4.6M.

4. Ordering Information

4.1 The inquiry and order for material under this specification shall include the following as required to describe the material adequately:

4.1.1 Specification designation, year date, and grade, issue date and revision letter,

4.1.2 Quantity, number of pieces,

4.1.3 Dimensions (see Section 9),

4.1.4 Options in accordance with 8.2.2.1, 9.1, 9.2, 10.3, and 12, and

4.1.5 Supplementary Requirements, if any.

4.2 *Coatings*—Coatings are prohibited unless specified by the purchaser (see Supplementary Requirements S7 and S8). When coated nuts are ordered, the purchaser should take special care to ensure that Appendix X2 is thoroughly understood.

4.3 See Supplementary Requirement S3 for nuts to be used in low temperature applications (Specification A 320/A 320M).

5. Common Requirements

5.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 962/A 962M, this specification shall prevail.

6. Manufacture (Process)

6.1 Stainless steels for all types of Grade 6 and 8 nuts shall be made by one of the following processes:

6.1.1 Electric-furnace (with separate degassing and refining optional),

6.1.2 Vacuum induction furnace, or

6.1.3 Either of the above followed by electroslag remelting, or consumable-arc remelting.

6.2 The steel producer shall exercise adequate control to eliminate excessive unhomogeneity, nonmetallics, pipe, porosity, and other defects.

6.3 Grades 1 and 2 nuts shall be hot or cold forged, or shall be machined from hot-forged, hot-rolled, or cold-drawn bars.

6.3.1 All Grade 1 and 2 nuts made by cold forging or by machining from cold-drawn bars shall be stress-relief annealed at a temperature of at least 1000 °F [538 °C].

6.3.2 Grade 1 and 2 nuts made by hot forging or by machining from hot-forged or hot-rolled bars need not be given any stress relief annealing treatment.

6.4 Grades 2H, 2HM, 3, 4, 6, 6F, 7, 7M, and 16 nuts shall be hot- or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and shall be heat treated to meet the required mechanical properties. These grades shall be reheated above the critical range of the steel, quenched in a suitable medium, and then tempered at a temperature not less than the following:

Grade	Minimum Tempering Temperature, °F [°C]
2H	850 [455]
2HM	1150 [620]
3	1050 [565]
4	1100 [595]
6 and 6F	1100 [595]
7	1100 [595]
7M	1150 [620]
16	1200 [650]

Nuts machined from bar heat treated in accordance with this specification need not be reheat-treated. For Grade 2HM and 7M nuts, a final stress relief shall be done at or above the minimum tempering temperature after all forming, machining, and tapping operations. This final stress relief may be the tempering operation.

6.4.1 Grade 6 and 6F nuts shall be tempered for a minimum of 1 h at the temperature.

6.5 Grades 8, 8C, 8M, 8T, 8F, 8P, 8N, 8MN, 8R, 8S, 8LN, 8MLN, 8MLCuN, and 9C nuts shall be hot or cold forged, or shall be machined from hot-forged, hot-rolled or cold-drawn bars.

6.6 Grades 8A, 8CA, 8MA, 8TA, 8FA, 8PA, 8NA, 8MNA, 8RA, 8SA, 8LNA, 8MLNA, 8MLCuNA, and 9CA nuts shall be hot- or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and the nuts shall subsequently be carbide-solution treated by heating them for a sufficient time at a temperature to dissolve chromium carbides followed by cooling at a rate sufficient to prevent reprecipitation of the carbides.

7. Chemical Composition

7.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 1.

TABLE 1 Chemical Requirements[A,B,C]

Grade Symbol	Material	UNS Number	Carbon, %	Manganese, %	Phosphorus, %	Sulfur,[D] %	Silicon, %	Chromium, %	Nickel, %	Molybdenum, %	Titanium, %	Columbium and Tantalum, %	Nitrogen, %	Other Elements, %
1	carbon		0.15 min	1.00	0.040	0.050	0.40	. . .	. . .	. . .	. . .	. . .	. . .	. . .
2, 2HM, and 2H	carbon		0.40 min	1.00	0.040	0.050	0.40	. . .	. . .	. . .	. . .	. . .	. . .	. . .
4	carbon, molybdenum		0.40–0.50	0.70–0.90	0.035	0.040	0.15–0.35	. . .	. . .	0.20–0.30	. . .	. . .	. . .	. . .
3	Type 501		0.10 min	1.00	0.040	0.030	1.00	4.0–6.0	. . .	0.40–0.65	. . .	. . .	. . .	. . .
6	Type 410	S41000	0.15	1.00	0.040	0.030	1.00	11.5–13.5	. . .	. . .	. . .	. . .	. . .	. . .
6F	Type 416	S41600	0.15	1.25	0.060	0.15 min	1.00	12.0–14.0	. . .	. . .	. . .	. . .	. . .	. . .
6F	Type 416Se	S41623	0.15	1.25	0.060	0.060	1.00	12.0–14.0	. . .	. . .	. . .	. . .		Selenium, 0.15 min
7, 7M	Type 4140/ 4142/ 4145, 4140H, 4142H, 4145H		0.37–0.49	0.65–1.10	0.035	0.04	0.15–0.35	0.75–1.20	. . .	0.15–0.25	. . .	. . .	. . .	. . .
8, 8A	Type 304	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	. . .	. . .
8C, 8CA	Type 347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	10 x carbon content, min	. . .	. . .
8M, 8MA	Type 316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	. . .	. . .	. . .	. . .
8T, 8TA	Type 321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	5 x (C+N) min - 0.70 max	. . .	. . .	. . .
8F, 8FA	Type 303	S30300	0.15	2.00	0.20	0.15 min	1.00	17.0–19.0	8.0–10.0	. . .	. . .	. . .	. . .	. . .
8F, 8FA	Type 303Se	S30323	0.15	2.00	0.20	0.06	1.00	17.0–19.0	8.0–10.0	. . .	. . .	. . .		Selenium, 0.15 min
8P, 8PA	Type 305 with restricted carbon	S30500	0.08	2.00	0.045	0.030	1.00	17.0–19.0	11.0–13.0	. . .	. . .	. . .	. . .	. . .
8N, 8NA	Type 304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	0.10–0.16	
8LN, 8LNA	Type 304LN	S30453	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	0.10–0.16	
8MN, 8MNA	Type 316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	. . .	. . .	0.10–0.16	
8MLN, 8MLNA	Type 316LN	S31653	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	. . .	. . .	0.10–0.16	
8R, 8RA[E]	XM19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	. . .	0.10–0.30	0.20–0.40	Vanadium, 0.10–0.30
8S, 8SA		S21800	0.10	7.0–9.0	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	. . .	. . .	. . .	0.08–0.18	
8MLCuN, 8MLCuNA	S31254	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	. . .	. . .	0.18–0.22	Copper, 0.50–1.00
9C, 9CA	N08367	N08367	0.030	2.00	0.040	0.030	1.00	20.0-22.0	23.5- 25.5	6.0-7.0			0.18-0.25	Copper 0.75
16	Chromium Molybdenum Vanadium		0.36–0.47	0.45–0.70	0.035	0.040	0.15–0.35	0.80–1.15	. . .	0.50–0.65	. . .	. . .	. . .	Vanadium, 0.25–0.35 Aluminum[B] 0.015

[A] The intentional addition of Bi, Se, Te, and Pb is not permitted except for Grades 6F, 8F, and 8FA, in which Se is specified and required.
[B] Total aluminum, soluble and insoluble.
[C] Maximum, unless minimum or range is indicated.
[D] Because of the degree to which sulfur segregates, product analysis for sulfur over 0.060 % max is not technologically appropriate.
[E] As described in Specification A 276.

8. Mechanical Requirements

8.1 *Hardness Test*:

8.1.1 *Requirements*:

8.1.1.1 All nuts shall meet the hardness requirements specified in Table 2.

8.1.1.2 Sample nuts of Grades 1, 2, 2H, 2HM, 3, 4, 7, 7M, and 16 which have been given the treatment described in 8.1.5 shall meet the minimum hardness specified in Table 2.

8.1.2 *Number of Tests*— (Grades 1, 2, 2H, 3, 4, 7, and 16 and all types of Grade 6):

8.1.2.1 Tests on the number of sample nuts in accordance with the following table shall be performed by the manufacturer following all production heat treatments:

Lot Size	Samples
Up to 800	1
801 to 8000	2
8001 to 22 000	3
Over 22 000	5

8.1.2.2 In addition, a hardness test shall be performed by the manufacturer in accordance with 8.1.5 on one sample nut selected from each nominal diameter and series from each grade and heat number following completion of all production heat treatments.

8.1.3 *Number of Tests, Grades 2HM and 7M*:

8.1.3.1 Each nut shall be tested by Brinell or Rockwell methods to ensure product conformance.[5]

8.1.3.2 In addition, 8.1.2.2 shall be met.

8.1.4 *Number of Tests, All Types of Grade 8*—Tests on the number of sample nuts in accordance with 8.1.2.1 shall be performed by the manufacturer.

8.1.5 *Test 2*—In addition to the testing required by 8.1.2.1 the manufacturer shall also perform hardness tests on sample nuts after the following test heat treatment. After completion of all production heat treatments heat the specimen nuts to the temperatures indicated below for 24 h, then slow cool. Test at room temperature.

Grade[A]	Temperature, °F [°C]
1	850 [455]
2, 2H, 2HM	1000 [540]
3, 4, 7, 7M	1100 [590]
16	1200 [650]

[A]Nuts intended to be coated with zinc or cadmium (marked in accordance with the requirements of Supplementary Requirement S8) are not subjected to the requirements of 8.1.5 (See Appendix X2).

8.1.5.1 *Special Requirement, Grades 2HM and 7M*—Preparation of Grades 2HM and 7M nuts for hardness test and the hardness test itself shall be performed with consideration to (*1*) protect legibility of markings; (*2*) minimize exterior dimensional changes; and (*3*) maintain thread fit.

8.2 *Proof Load Test*:

8.2.1 *Requirements*—All nuts shall be capable of withstanding the proof loads specified in Table 3 and Table 4. However, nuts manufactured to dimensions and configurations other than those covered by ANSI B 1.1, ANSI B 1.13M, ANSI B 18.2.2, and B 18.2.4.6M are not subject to the proof load test.

8.2.2 *Number of Tests*:

8.2.2.1 The manufacturer shall test the number of nuts specified in 8.1.2.1 following all production heat treatments. Nuts that would require a proof load in excess of 160 000 lb/f or 705 kN may be furnished on the basis of minimum hardness requirements. Testing of nuts requiring a proof load in excess of 160 000 lb/f or 705 kN is covered in Supplementary Requirements S1 amd S4.

8.2.3 *Test Method*—The test shall be run using a threaded mandrel or a test bolt in accordance with Specification A 962/A 962M.

8.3 *Cone Proof Load Test:*

8.3.1 *Requirements*—This test shall be performed only when visible surface discontinuities become a matter of issue between the manufacturer and the purchaser. Nuts in the size range ¼ to 1½ in. inclusive and M6 to M36 inclusive shall be proof load tested. Nuts not in this size range and all types of Grade 8 nuts are not subject to this test. Also, nuts manufactured to dimensions and configurations other than those covered by Specification A 962/A 962M, ANSI B 1.1, ANSI B 1.13M, ANSI B 18.2.2, and ANSI B 18.2.4.6M are not

[5] An underline as a marking requirement for grades 2HM and 7M has been removed but is permitted.

TABLE 2 Hardness Requirements

Grade and Type	Completed Nuts			Sample Nut after Treatment as in 8.1.5	
	Brinell Hardness	Rockwell Hardness		Brinell Hardness, min	Rockwell Hardness B Scale, min
		C Scale	B Scale		
1	121 min	...	70 min	121	70
2	159 to 352	...	84 min	159	84
2H to 1½ in. or M36, incl	248 to 327	24 to 35	...	179	89
2H over 1½ in. or M36	212 to 327	35 max	95 min	147	79
2HM and 7M	159 to 235	...	84 to 99	159	84
3, 4, 7, and 16	248 to 327	24 to 35	...	201	94
6 and 6F	228 to 271	20 to 28	...	...	...
8, 8C, 8M, 8T, 8F, 8P, 8N, 8MN, 8LN, 8MLN, 8MLCuN, and 9C	126 to 300	32 max	60 min	...	...
8A, 8CA, 8MA, 8TA, 8FA, 8PA, 8NA, 8MNA, 8LNA, 8MLNA, 8MLCuNA, and 9CA	126 to 192	...	60 to 90	...	...
8R, 8RA, 8S, and 8SA	183 to 271	25 max	88 min	...	...

TABLE 3 Proof Load Using Threaded Mandrel — Inch Series

NOTE 1—Proof loads are not design loads.

Nominal Size, in.	Threads per Inch	Stress Area in.^{2}	Proof Load, lbf^A Grade 1 Heavy Hex^B	Grade 1 Hex^C	Grades 2, 2HM, 6, 6F, 7M Heavy Hex^D	Grades 2, 2HM, 6, 6F, 7M Hex^E	Grades 2H, 3, 4, 7, 16 Heavy Hex^F	Grades 2H, 3, 4, 7, 16 Hex^G
1⁄4	20	0.0316	4 130	3 820	4 770	4 300	5 570	4 770
5⁄16	18	0.0524	6 810	6 290	7 860	7 070	9 170	7 860
3⁄8	16	0.0774	10 080	9 300	11 620	10 460	13 560	11 620
7⁄16	14	0.1063	13 820	12 760	15 940	14 350	18 600	15 940
1⁄2	13	0.1419	18 450	17 030	21 280	19 160	24 830	21 280
9⁄16	12	0.182	23 660	21 840	27 300	24 570	31 850	27 300
5⁄8	11	0.226	29 380	27 120	33 900	30 510	39 550	33 900
3⁄4	10	0.334	43 420	40 080	50 100	45 090	58 450	50 100
7⁄8	9	0.462	60 060	55 440	69 300	62 370	80 850	69 300
1	8	0.606	78 780	72 720	90 900	81 810	106 000	90 900
1 1⁄8	8	0.790	102 700	94 800	118 500	106 700	138 200	118 500
1 1⁄4	8	1.000	130 000	120 000	150 000	135 000	175 000	150 000
1 3⁄8	8	1.233	160 200	148 000	185 000	166 500	215 800	185 000
1 1⁄2	8	1.492	194 000	170 040	223 800	201 400	261 100	223 800

Nominal Size, in.	Threads per Inch	Stress Area in.^{2}	All Types of Grade 8, Grades 9C and 9CA Heavy Hex^H	All Types of Grade 8, Grades 9C and 9CA Hex^I
1⁄4	20	0.0316	2 540	2 380
5⁄16	18	0.0524	4 190	3 930
3⁄8	16	0.0774	6 200	5 810
7⁄16	14	0.1063	8 500	7 970
1⁄2	13	0.1419	11 350	10 640
9⁄16	12	0.182	14 560	13 650
5⁄8	11	0.226	18 080	16 950
3⁄4	10	0.334	26 720	25 050
7⁄8	9	0.462	36 960	34 650
1	8	0.606	48 480	45 450
1 1⁄8	8	0.790	63 200	59 250
1 1⁄4	8	1.000	80 000	75 000
1 3⁄8	8	1.233	98 640	92 450
1 1⁄2	8	1.492	119 360	111 900

^{A} See limit for proof load test in 8.2.2.1. The proof load for jam nuts shall be 46 % of the tabulated load.
^{B} Based on proof stress of 130 000 psi.
^{C} Based on proof stress of 120 000 psi.
^{D} Based on proof stress of 150 000 psi.
^{E} Based on proof stress of 135 000 psi.
^{F} Based on proof stress of 175 000 psi.
^{G} Based on proof stress of 150 000 psi.
^{H} Based on proof stress of 80 000 psi.
^{I} Based on proof stress of 75 000 psi.

subject to the cone proof load test. The cone proof load applied shall be determined in accordance with the Cone Proof Load requirements in Specification A 962/A 962M (tables or formulae or both) based upon the proof stresses shown in Table 5 and Table 6 of Specification A 194/A 194M.

8.3.2 *Number of Tests*—The manufacturer shall sample and test the number of nuts specified in 8.1.2.1. The lot shall be considered acceptable if the sample nut(s) withstand(s) application of the cone proof load without failure.

9. Dimensions

9.1 Nuts shall be hexagonal in shape, and in accordance with the dimensions for the hex or heavy hex series, as required, by ANSI B 18.2.2 and ANSI B 18.2.4.6M. Unless otherwise specified, the American National Standard Heavy Hex Series shall be used and nuts shall be either double chamfered or have a machined or forged washer face, at the option of the manufacturer, and, conform to the angularity requirements of ANSI B 18.2.2 and ANSI B 18.2.4.6M.

9.2 Unless otherwise specified, threads shall be in accordance with ANSI B 1.1 or ANSI B 1.13M, and shall be gaged in accordance with ANSI B 1.2 and ANSI B 1.13M as described in 9.2.1 and 9.2.2.

9.2.1 Nuts up to and including 1 in. nominal size shall be UNC Series Class 2B fit. Metric nuts up to and including M24 nominal size shall be coarse thread series tolerance 6H.

TABLE 4 Proof Load Using Threaded Mandrel — Metric

NOTE 1—Proof loads are not design loads.

Nominal Size, mm	Threads Pitch	Stress Area mm²	Proof Load, kN[A]					
			Grade 1		Grades 2, 2HM, 6, 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[E]	Heavy Hex[F]	Hex[G]
M6	1.0	20.1	18.0	16.6	20.8	18.7	29.2	20.8
M8	1.25	36.6	32.8	30.2	37.9	34.0	44.1	37.9
M10	1.50	58.0	51.9	47.9	60.0	53.9	69.9	60.0
M12	1.75	84.3	75.5	69.5	87.3	78.4	101.6	87.3
M14	2.0	115.0	102.9	94.9	119.0	107.0	138.6	119.0
M16	2.0	157.0	140.5	129.5	162.5	146.0	189.2	162.5
M20	2.5	245.0	219.3	202.1	253.6	227.8	295.2	253.6
M22	2.5	303.0	271.2	249.9	313.6	281.8	365.1	313.6
M24	3.0	353.0	315.9	291.2	365.4	328.3	425.4	365.4
M27	3.0	459.0	411.0	378.7	475.1	426.9	553.4	475.1
M30	3.5	561.0	502.1	462.8	580.6	521.7	676.0	580.6
M36	4.0	817.0	731.2	674.0	845.6	759.8	984.5	845.6

Nominal Size, mm	Thread Pitch	All Types of Grade 8, and Grades 9C and 9CA		
		Stress Area, mm²	Heavy Hex[H]	Hex[I]
M6	1.0	20.1	11.1	10.4
M8	1.25	36.6	20.1	18.8
M10	1.50	58.0	31.9	29.9
M12	1.75	84.3	46.4	43.4
M14	2.0	115.0	63.3	59.2
M16	2.0	157.0	86.4	80.9
M20	2.5	245.0	134.8	126.2
M22	2.5	303.0	166.7	156.0
M24	3.0	353.0	194.2	181.8
M27	3.0	459.0	252.5	236.4
M30	3.5	561.0	308.6	288.9
M36	4.0	817.0	449.4	420.8

[A] See limit for proof load test in 8.2.2.1. The proof load for jam nuts shall be 46 % of the tabulated load.
[B] Based on proof stress of 895 MPa.
[C] Based on proof stress of 825 MPa.
[D] Based on proof stress of 1035 MPa.
[E] Based on proof stress of 930 MPa.
[F] Based on proof stress of 1205 MPa.
[G] Based on proof stress of 1035 MPa.
[H] Based on proof stress of 550 MPa.
[I] Based on proof stress of 515 MPa.

TABLE 5 Proof Stress Using 120° Hardened Steel Cone — Inch

Type	Proof Stress – psi, Minimum		
	Grade 1	Grades 2, 2HM, 6, 6F & 7M	Grades 2H 3, 4, 7, & 16
Hex	120 000	135 000	150 000
Heavy Hex	130 000	150 000	175 000

TABLE 6 Proof Stress Using 120° Hardened Steel Cone — Metric

Type	Proof Stress – MPa, Minimum		
	Grade 1	Grades 2, 2HM, 6, 6F & 7M	Grades 2H 3, 4, 7, & 16
Hex	825	930	1035
Heavy Hex	895	1035	1205

9.2.2 Nuts over 1 in. nominal size shall be either UNC Series Class 2B fit or 8 UN Series Class 2B fit. Unless otherwise specified, the 8 UN series shall be furnished. Metric nuts over M24 nominal size shall be coarse thread series tolerance 6H.

10. Workmanship, Finish, and Appearance

10.1 Nuts shall be free of defects and shall be good commercial finish.

10.2 If visible surface imperfections in size ¼ through 1½ in. and M6 through M36 and in any grade other than Grade 8 become a matter of issue between the manufacturer and the purchaser, the cone proof load test described in 8.3 shall be employed.

10.3 If a scale-free bright finish is required, this shall be specified on the purchase order.

11. Retests

11.1 Provisions for retests by the purchaser and his representative are specified in Supplementary Requirement S2.

12. Certification

12.1 The producer of nuts shall furnish a certification to the purchaser or his representative showing the results of the chemical analysis, macroetch examination (Carbon and Alloy Steels Only), mechanical tests, and the minimum tempering temperature for nuts of Grades 2H, 2HM, 3, 4, 6, 6F, 7, and 7M.

12.2 Certification shall also include at least the following:

12.2.1 A statement that the fasteners were manufactured, sampled, tested and inspected in accordance with the specification and any supplementary requirements or other requirements designated in the purchase order or contract and was found to meet those requirements.

12.2.2 The specification number, year date, and identification symbol.

13. Product Marking

13.1 All nuts shall bear the manufacturer's identification mark.

13.2 Nuts shall be legibly marked on one face to indicate the grade and process of the manufacturer, as presented in Table 7. Marking of wrench flats or bearing surfaces is not permitted unless agreed upon between manufacturer and purchaser.

13.3 For purposes of identification marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

14. Keywords

14.1 bolting; chemical analysis; coated; marking on fasteners; plated

TABLE 7 Marking of Nuts

Grade and Type	Nuts Hot-Forged or Cold-Punched	Nuts Machined from Bar Stock	Nuts Manufactured in Accordance with 6.6
1	1	1B	...
2	2	2B	...
2H[A]	2H	2HB	...
2HM[A]	2HM	2HMB	...
3	3	3B	...
4	4	4B	...
4L[B]	4L	4BL	. . .
6	6	6B	. . .
6F	6F	6FB	...
7	7	7B	...
7L[B]	7L	7BL	...
7M[A]	7M	7MB	...
8	8	8B	8A
8C	8C	8CB	8CA
8M	8M	8MB	8MA
8T	8T	8TB	8TA
8F	8F	8FB	8FA
8P	8P	8PB	8PA
8N	8N	8NB	8NA
8MN	8MN	8MNB	8MNA
8R	8R	8RB	8RA
8S	8S	8SB	8SA
8LN	8LN	8LNB	8LNA
8MLN	8MLN	8MLNB	8MLNA
8MLCuN	8MLCuN	8MLCuNB	8MLCuNA
9C	9C	9CB	9CA
16	16	16B	

[A] The letters H and M indicate heat-treated nuts (see Section 6).
[B] See Supplementary Requirement S3.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Strain-Hardened Austenitic Steel Nuts

S1.1 Strain hardened Grades 8, 8C, 8T, 8M, 8F, 8P, 8N, or 8MN nuts may be specified. When Supplementary Requirement S1 is invoked in the order, nuts shall be machined from cold drawn bars or shall be cold forged to shape. No subsequent heat treatment shall be performed on the nuts. Nuts made in accordance with this requirement shall be proof load tested in accordance with 8.2.2.1 and shall withstand the proof load specified in Table 8 and Table 9. Testing nuts requiring proof loads over 160 000 lbf or 705 kN is only required when Supplementary Requirement S4 is invoked. The hardness limits of Table 2 do not apply to strain hardened nuts. Nuts

TABLE 8 Proof Load Testing of Strain Hardened Nuts Using Threaded Mandrel — Inch Series

NOTE 1—Proof loads are not design loads.

			Proof Load, lbf[A]			
Nominal Size, in.	Threads per in.	Stress Area, in.^{2}	Grade 8M (strain hardened)	Grade 8M (strain hardened)	All Other Types of Grade 8 (strain hardened)	All Other Types of Grade 8 (strain hardened)
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[B]
¼	20	0.0316	3 480	3 160	3 950	3 480
5⁄16	18	0.0523	5 760	5 240	6 550	5 760
⅜	16	0.0774	8 510	7 740	9 675	8 510
7⁄16	14	0.1063	11 690	10 630	13 290	11 690
½	13	0.1419	15 610	14 190	17 740	15 610
9⁄16	12	0.182	20 020	18 200	22 750	20 020
⅝	11	0.226	24 860	22 600	28 250	24 860
¾	10	0.334	36 740	33 400	41 750	36 740
⅞	9	0.462	46 200	41 580	53 130	46 200
1	8	0.606	60 600	54 540	69 690	60 600
1⅛	8	0.790	75 050	67 150	82 950	75 050
1¼	8	1.000	95 000	85 000	105 000	95 000
1⅜	8	1.233	110 970	98 640	123 300	110 970
1½	8	1.492	134 280	119 360	149 200	134 280

[A] The proof load for jam nuts shall be 46 % of the tabulated value.
[B] Based on proof stress of 110 000 psi up to ¾ in.; 100 000 psi ⅞ to 1 in.; 95 000 psi 1⅛ to 1¼ in.; 90 000 psi 1⅜ to 1½ in.
[C] Based on proof stress of 100 000 psi up to ¾ in.; 90 000 psi ⅞ to 1 in.; 85 000 psi 1⅛ to 1¼ in.; 80 000 psi 1⅜ to 1½ in.
[D] Based on proof stress of 125 000 psi up to ¾ in.; 115 000 psi ⅞ to 1 in.; 105 000 psi 1⅛ to 1¼ in.; 100 000 psi 1⅜ to 1½ in.

TABLE 9 Proof Load Testing of Strain Hardened Nuts Using Threaded Mandrel — Metric

NOTE 1—Proof loads are not design loads.

			Proof Load, kN[A]			
Nominal Size, mm	Thread Pitch	Stress Area, mm^2	Grade 8M (strain hardened)	Grade 8M (strain hardened)	All Other Types of Grade 8 (strain hardened)	All Other Types of Grade 8 (strain hardened)
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[B]
M6	1.0	20.1	15.3	13.9	17.3	15.3
M8	1.25	36.6	27.8	25.3	31.3	27.8
M10	1.50	58.0	44.1	40.0	49.9	44.1
M12	1.75	84.3	64.1	58.2	72.5	64.1
M14	2.0	115.0	87.4	79.4	98.9	87.4
M16	2.0	157.0	119.3	108.3	135.0	119.3
M20	2.5	245.0	186.2	169.0	210.9	186.2
M22	2.5	303.0	209.0	187.9	240.9	209.0
M24	3.0	353.0	243.5	218.9	280.6	243.5
M27	3.0	459.0	300.6	268.5	332.7	300.6
M30	3.5	561.0	367.5	328.2	406.7	367.5
M36	4.0	817.0	506.5	449.4	563.7	506.5

[A] The proof load for jam nuts shall be 46 % of the tabulated value.
[B] Based on proof stress of 760 MPa up to M20 mm; 690 MPa M22 to M24 mm; 655 MPa M27 to M30; and 620 MPa for M36.
[C] Based on proof stress of 690 MPa up to M20 mm; 620 MPa M22 to M24 mm; 585 MPa M27 to M30; and 550 MPa for M36.
[D] Based on proof stress of 860 MPa up to M20 mm; 795 MPa M22 to M24 mm; 725 MPa M27 to M30 mm; and 690 MPa for M36.

made in accordance with this requirement shall be marked with the Grade symbol underlined.

S2. Retests by Purchaser's Representative

S2.1 The purchaser's representative may select two nuts per keg (200-lb unit [90-kg]) for sizes ⅝ in. and M16 and smaller, one nut per keg for sizes over ⅝ in. and M16 up to and including 1½ in. and M36, and one nut per every two kegs for sizes larger than 1½ in. and M36, which shall be subjected to the tests specified in Section 8.

S3. Low-Temperature Requirements for Grade 4, Grade 7 or Grade 7M Nuts

S3.1 When low-temperature requirements are specified for Grade 4 or Grade 7 nuts, the Charpy test procedures and requirements as defined in Specification A 320/A 320M for

Grade L7 shall apply. When low-temperature requirements are specified for Grade 7M nuts, the Charpy test procedures and requirements as defined in Specification A 320/A 320M for Grade L7M shall apply. Depending on the size of nuts, separate test samples of the same heat may be required and shall be processed through heat treatment with the nuts for which the test is to apply. Impact testing is not required when the bar stock or nut is smaller than 5⁄8 in. [16 mm] in diameter.

S3.2 An“ L” shall be added to the marking, as shown in Table 7, for nuts so tested.

S4. Proof Load Tests of Large Nuts

S4.1 Proof load testing of nuts requiring proof loads of over 160 000 lbf or 705 kN is required. Testing shall be performed in accordance with 8.2 to the loads required in Table 10 and Table 11. The maximum load will be based entirely on the equipment available.

S5. Control of Product by Heat Number

S5.1 When control of nuts by actual heat analysis is required and this supplementary requirement is specified, the manufacturer shall identify the completed nuts in each shipment by the actual heat number. When this supplementary requirement is specified, a certificate including the results of the actual production tests of each test lot together with the heat chemical analysis shall be furnished by the manufacturer.

S6. Grain Size Requirements for Non H Grade Austenitic Steels Used Above 1000 °F

S6.1 For design metal temperatures above 1000 °F [540 °C], the material shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E 112. The grain size so determined shall be reported on the Certificate of Test.

S7. Coating on Nuts

S7.1 It is the purchaser's responsibility to specify in the purchase order all information required by the coating facility. Examples of such information may include but are not limited to the following:

S7.1.1 Reference to the appropriate coating specification and type, thickness, location, modification to dimensions, and hydrogen embrittlement relief.

S7.1.2 Reference to Specifications A 153/A 153M, B 695, B 696, B 766, F 1941, Test Method F 1940, or other standards.

S8. Marking Coated Nuts

S8.1 Nuts coated with zinc shall have an asterisk (*) marked after the grade symbol. Nuts coated with cadmium shall have a plus sign (+) marked after the grade symbol.

TABLE 10 Proof Load for Large Heavy Hex Nuts — Inch[A]

Nominal Size, in.	Threads per in.	Stress Area, in.^{2}	Proof Load, lbf[B]		
			Grade 1 Heavy Hex	Grades 2, 2HM, 6, 6F, 7M Heavy Hex	Grades 2H, 3, 4, 7, 16 Heavy Hex
1⅝	8	1.78	231 400	267 000	311 500
1¾	8	2.08	270 400	312 000	364 000
1⅞	8	2.41	313 300	361 500	421 800
2	8	2.77	360 100	415 500	484 800
2¼	8	3.56	462 800	534 000	623 000
2½	8	4.44	577 200	666 000	777 000
2¾	8	5.43	705 900	814 500	950 250

[A] ANSI B 18.2.2 in the size range over 1½ in. provides dimensions only for heavy hex nuts. Refer to 8.3.1.

[B] Proof loads for nuts of larger dimensions or other thread series may be calculated by multiplying the thread stress area times the proof stress in the notes to Table 3 or Table 8. The proof load for jam nuts shall be 46 % of the tabulated load.

TABLE 11 Proof Load for Large Heavy Hex Nuts — Metric[A]

Nominal Size, mm	Thread Pitch	Stress Area, mm²	Proof Load, kN[B]		
			Grade 1 Heavy Hex	Grades 2, 2HM, 6, 6F, 7M Heavy Hex	Grades 2H, 3, 4, 7, 16 Heavy Hex
M42	4.5	1120	1002.4	1159.2	1349.6
M48	5	1470	1315.7	1521.4	1771.4
M56	5.5	2030	1816.9	2101.0	2446.2
M64	6	2680	2398.6	2773.8	3229.4
M72	6	3460	3096.7	3581.1	4169.3

[A] ANSI B 18.2.4.6M in the size range over M36 provides dimensions only for heavy hex nuts. Refer to 7.3.1.
[B] Proof loads for nuts of larger dimensions or other thread series may be calculated by multiplying the thread stress area times the proof stress in the notes to Table 4 or Table 9. The proof load for jam nuts shall be 46 % of the tabulated load.

APPENDIXES

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar, so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening. Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined.

X2. COATINGS AND APPLICATION LIMITS

X2.1 Use of coated fasteners at temperatures above approximately one-half the melting point (Fahrenheit or Celsius) of the coating is not recommended unless consideration is given to the potential for liquid and solid metal embrittlement, or both. The melting point of elemental zinc is approximately 780 °F [415 °C]. Therefore, application of zinc coated fasteners should be limited to temperatures less than 390 °F [210 °C]. The melting point of cadmium is approximately 600 °F [320 °C]. Therefore, application of cadmium coated fasteners should be limited to temperatures less than 300 °F [160 °C].

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 07, that may impact the use of this specification. (Approved March 1, 2007)

(*1*) Added reference to Test Method F 1940 in S7.1.2.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 06a, that may impact the use of this specification. (Approved February 1, 2007)

(*1*) Revised cone proof load test requirements to reference recent changes to Specification A 962/A 962M and Test Methods and Definitions A 370.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 06, that may impact the use of this specification. (Approved June 15, 2006)

(*1*) Moved Requirements for Coated Fasteners from body of text to Supplementary Requirements S7 and S8.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 05b, that may impact the use of this specification. (Approved March 15, 2006)

(*1*) Revised Table 2 to remove multiple lines with the same ranges, specify max HRC rather than HRB over 100, and remove inconsistencies with format.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 05a, that may impact the use of this specification. (Approved December 1, 2005)

(*1*) Revised Supplementary Requirement S3.1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 05, that may impact the use of this specification. (Approved September 15, 2005)

(*1*) Increased proof load requirement in 8.2.2.1, Supplementary Requirement S1, Supplementary Requirement S4, Table 10, and Table 11.

Designation: A 194/A 194M – 08

Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both[1]

This standard is issued under the fixed designation A 194/A 194M; 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*

1.1 This specification[2] covers a variety of carbon, alloy, and martensitic stainless steel nuts in the size range ¼ through 4 in. and metric M6 through M100 nominal. It also covers austenitic stainless steel nuts in the size range ¼ in. and M6 nominal and above. These nuts are intended for high-pressure or high-temperature service, or both. Grade substitutions without the purchaser's permission are not allowed.

1.2 Bars from which the nuts are made shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be solution annealed or annealed and strain-hardened. When annealed and strain hardened austenitic stainless steel is ordered in accordance with Supplementary Requirement S1, the purchaser should take special care to ensure that 8.2.2, Supplementary Requirement S1, and Appendix X1 are thoroughly understood.

1.3 Supplementary requirements (S1 through S8) of an optional nature are provided. These shall apply only when specified in the inquiry, contract, and order.

1.4 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable" M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI units are to be regarded separately as standard. 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. Within the text, the SI units are shown in brackets.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 276 Specification for Stainless Steel Bars and Shapes
A 320/A 320M Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service
A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
B 696 Specification for Coatings of Cadmium Mechanically Deposited
B 766 Specification for Electrodeposited Coatings of Cadmium
E 112 Test Methods for Determining Average Grain Size
F 1940 Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners
F 1941 Specification for Electrodeposited Coatings on Threaded Fasteners (Unified Inch Screw Threads (UN/UNR))

2.2 *American National Standards:*[4]

B 1.1 Unified Screw Threads
B 1.2 Gages and Gaging for Unified Inch Screw Threads
B 1.13M Metric Screw Threads
B 18.2.2 Square and Hex Nuts
B 18.2.4.6M Metric Heavy Hex Nuts

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-194 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 National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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

3.1.1 *Austenitic Grades*—All grades with a prefix of "8" or "9".

3.1.2 *Ferritic Grades*—Grades 1, 2, 2H, 2HM, 3, 4, 6, 6F, 7, 7M, and 16.

3.1.3 *Lot*—Unless otherwise specified (see Discussion below), a lot is the quantity of nuts of a single nominal size and grade produced by the same manufacturing process.

3.1.3.1 *Discussion*—When Supplementary Requirement S5 is invoked on the purchase order, the following definitions of a lot shall apply:

3.1.3.2 *For Grade 8 Nuts*—The quantity of all the nuts of a single nominal diameter and grade made from the same heat of steel and made by the same manufacturing process.

3.1.3.3 *For All Other Grade Nuts*— (see 8.2 and 8.1.2.1)— All the nuts of a single nominal diameter and grade made from the same heat number and heat treated in the same batch if batch-type heat treating equipment is used or heat treated in the same continuous run of not more than 8 h under the same conditions if continuous-type heat treating equipment is used.

3.1.4 *Type*

3.1.4.1 *For Grade 8 Nuts*—Variations within the grade designated by a letter and differentiated by chemistry and by manufacturing process.

3.1.4.2 *For Grade 6 Nuts*—Variations within the grade designated by the letter F as differentiated by chemical additions made for machineability.

3.1.5 *Series*—The dimensional relationship and geometry of the nuts as described in ANSI B 18.2.2 or B 18.2.4.6M.

4. Ordering Information

4.1 The inquiry and order for material under this specification shall include the following as required to describe the material adequately:

4.1.1 Specification designation, year date, and grade, issue date and revision letter,

4.1.2 Quantity, number of pieces,

4.1.3 Dimensions (see Section 9),

4.1.4 Options in accordance with 8.2.2.1, 9.1, 9.2, 10.3, and 12, and

4.1.5 Supplementary Requirements, if any.

4.2 *Coatings*—Coatings are prohibited unless specified by the purchaser (see Supplementary Requirements S7 and S8). When coated nuts are ordered, the purchaser should take special care to ensure that Appendix X2 is thoroughly understood.

4.3 See Supplementary Requirement S3 for nuts to be used in low temperature applications (Specification A 320/A 320M).

5. Common Requirements

5.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 962/A 962M, this specification shall prevail.

6. Manufacture (Process)

6.1 Stainless steels for all types of Grade 6 and 8 nuts shall be made by one of the following processes:

6.1.1 Electric-furnace (with separate degassing and refining optional),

6.1.2 Vacuum induction furnace, or

6.1.3 Either of the above followed by electroslag remelting, or consumable-arc remelting.

6.2 The steel producer shall exercise adequate control to eliminate excessive unhomogeneity, nonmetallics, pipe, porosity, and other defects.

6.3 Grades 1 and 2 nuts shall be hot or cold forged, or shall be machined from hot-forged, hot-rolled, or cold-drawn bars.

6.3.1 All Grade 1 and 2 nuts made by cold forging or by machining from cold-drawn bars shall be stress-relief annealed at a temperature of at least 1000 °F [538 °C].

6.3.2 Grade 1 and 2 nuts made by hot forging or by machining from hot-forged or hot-rolled bars need not be given any stress relief annealing treatment.

6.4 Grades 2H, 2HM, 3, 4, 6, 6F, 7, 7M, and 16 nuts shall be hot- or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and shall be heat treated to meet the required mechanical properties. These grades shall be reheated above the critical range of the steel, quenched in a suitable medium, and then tempered at a temperature not less than the following:

Grade	Minimum Tempering Temperature, °F [°C]
2H	850 [455]
2HM	1150 [620]
3	1050 [565]
4	1100 [595]
6 and 6F	1100 [595]
7	1100 [595]
7M	1150 [620]
16	1200 [650]

Nuts machined from bar heat treated in accordance with this specification need not be reheat-treated. For Grade 2HM and 7M nuts, a final stress relief shall be done at or above the minimum tempering temperature after all forming, machining, and tapping operations. This final stress relief may be the tempering operation.

6.4.1 Grade 6 and 6F nuts shall be tempered for a minimum of 1 h at the temperature.

6.5 Grades 8, 8C, 8M, 8T, 8F, 8P, 8N, 8MN, 8R, 8S, 8LN, 8MLN, 8MLCuN, and 9C nuts shall be hot or cold forged, or shall be machined from hot-forged, hot-rolled or cold-drawn bars.

6.6 Grades 8A, 8CA, 8MA, 8TA, 8FA, 8PA, 8NA, 8MNA, 8RA, 8SA, 8LNA, 8MLNA, 8MLCuNA, and 9CA nuts shall be hot- or cold-forged or shall be machined from hot-forged, hot-rolled, or cold-drawn bars and the nuts shall subsequently be carbide-solution treated by heating them for a sufficient time at a temperature to dissolve chromium carbides followed by cooling at a rate sufficient to prevent reprecipitation of the carbides.

7. Chemical Composition

7.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 1.

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TABLE 1 Chemical Requirements^{A,B,C,D}

Grade Symbol	Material	UNS Number	Carbon, %	Manganese, %	Phosphorus, %	Sulfur,^{E} %	Silicon, %	Chromium, %	Nickel, %	Molybdenum, %	Titanium, %	Columbium and Tantalum, %	Nitrogen, %	Other Elements, %
1	carbon		0.15 min	1.00	0.040	0.050	0.40	...	...	...	...	...	...	...
2, 2HM, and 2H	carbon		0.40 min	1.00	0.040	0.050	0.40	...	...	...	...	...	...	...
4	carbon, molybdenum		0.40–0.50	0.70–0.90	0.035	0.040	0.15–0.35	...	...	0.20–0.30	...	...	...	...
3	Type 501		0.10 min	1.00	0.040	0.030	1.00	4.0–6.0	...	0.40–0.65	...	...	...	...
6	Type 410	S41000	0.15	1.00	0.040	0.030	1.00	11.5–13.5	...	...	...	...	...	...
6F	Type 416	S41600	0.15	1.25	0.060	0.15 min	1.00	12.0–14.0	...	...	...	...	...	...
6F	Type 416Se	S41623	0.15	1.25	0.060	0.060	1.00	12.0–14.0	...	...	...	...		Selenium, 0.15 min
7, 7M	Type 4140/ 4142/ 4145, 4140H, 4142H, 4145H		0.37–0.49	0.65–1.10	0.035	0.04	0.15–0.35	0.75–1.20	...	0.15–0.25	...	...	...	...
8, 8A	Type 304	S30400	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	...	...
8C, 8CA	Type 347	S34700	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	...	10 x carbon content, min	...	...
8M, 8MA	Type 316	S31600	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	...	...	...	...
8T, 8TA	Type 321	S32100	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	...	5 x (C+N) min - 0.70 max	...	0.10	...
8F, 8FA	Type 303	S30300	0.15	2.00	0.20	0.15 min	1.00	17.0–19.0	8.0–10.0	...	...	...	...	...
8F, 8FA	Type 303Se	S30323	0.15	2.00	0.20	0.06	1.00	17.0–19.0	8.0–10.0	...	...	...		Selenium, 0.15 min
8P, 8PA	Type 305 with restricted carbon	S30500	0.08	2.00	0.045	0.030	1.00	17.0–19.0	11.0–13.0	...	...	...	...	...
8N, 8NA	Type 304N	S30451	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	0.10–0.16	
8LN, 8LNA	Type 304LN	S30453	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	...	...	...	0.10–0.16	
8MN, 8MNA	Type 316N	S31651	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	...	...	0.10–0.16	
8MLN, 8MLNA	Type 316LN	S31653	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	...	...	0.10–0.16	
8R, 8RA^{F}	XM19	S20910	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	...	0.10–0.30	0.20–0.40	Vanadium, 0.10–0.30
8S, 8SA		S21800	0.10	7.0–9.0	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	...	...	...	0.08–0.18	
8MLCuN, 8MLCuNA	S31254	S31254	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	...	...	0.18–0.22	Copper, 0.50–1.00
9C, 9CA	N08367	N08367	0.030	2.00	0.040	0.030	1.00	20.0-22.0	23.5- 25.5	6.0-7.0			0.18-0.25	Copper 0.75
16	Chromium Molybdenum Vanadium		0.36–0.47	0.45–0.70	0.035	0.040	0.15–0.35	0.80–1.15	...	0.50–0.65	...	...	...	Vanadium, 0.25–0.35 Aluminum^{B} 0.015

^{A} The intentional addition of Bi, Se, Te, and Pb is not permitted except for Grades 6F, 8F, and 8FA, in which Se is specified and required.
^{B} Total aluminum, soluble and insoluble.
^{C} Maximum, unless minimum or range is indicated.
^{D} Where ellipses (...) appear in this table there is no requirement.
^{E} Because of the degree to which sulfur segregates, product analysis for sulfur over 0.060 % max is not technologically appropriate.
^{F} As described in Specification A 276.

8. Mechanical Requirements

8.1 *Hardness Test*:

8.1.1 *Requirements*:

8.1.1.1 All nuts shall meet the hardness requirements specified in Table 2.

8.1.1.2 Sample nuts of Grades 1, 2, 2H, 2HM, 3, 4, 7, 7M, and 16 which have been given the treatment described in 8.1.5 shall meet the minimum hardness specified in Table 2.

8.1.2 *Number of Tests*— (Grades 1, 2, 2H, 3, 4, 7, and 16 and all types of Grade 6):

8.1.2.1 Tests on the number of sample nuts in accordance with the following table shall be performed by the manufacturer following all production heat treatments:

Lot Size	Samples
Up to 800	1
801 to 8000	2
8001 to 22 000	3
Over 22 000	5

8.1.2.2 In addition, a hardness test shall be performed by the manufacturer in accordance with 8.1.5 on one sample nut selected from each nominal diameter and series from each grade and heat number following completion of all production heat treatments.

8.1.3 *Number of Tests, Grades 2HM and 7M*:

8.1.3.1 Each nut shall be tested by Brinell or Rockwell methods to ensure product conformance.[5]

8.1.3.2 In addition, 8.1.2.2 shall be met.

8.1.4 *Number of Tests, All Types of Grade 8*—Tests on the number of sample nuts in accordance with 8.1.2.1 shall be performed by the manufacturer.

8.1.5 *Test 2*—In addition to the testing required by 8.1.2.1 the manufacturer shall also perform hardness tests on sample nuts after the following test heat treatment. After completion of all production heat treatments heat the specimen nuts to the temperatures indicated below for 24 h, then slow cool. Test at room temperature.

Grade[A]	Temperature, °F [°C]
1	850 [455]
2, 2H, 2HM	1000 [540]
3, 4, 7, 7M	1100 [590]
16	1200 [650]

[A]Nuts intended to be coated with zinc or cadmium (marked in accordance with the requirements of Supplementary Requirement S8) are not subjected to the requirements of 8.1.5 (See Appendix X2).

8.1.5.1 *Special Requirement, Grades 2HM and 7M*—Preparation of Grades 2HM and 7M nuts for hardness test and the hardness test itself shall be performed with consideration to (*1*) protect legibility of markings; (*2*) minimize exterior dimensional changes; and (*3*) maintain thread fit.

8.2 *Proof Load Test*:

8.2.1 *Requirements*—All nuts shall be capable of withstanding the proof loads specified in Table 3 and Table 4. However, nuts manufactured to dimensions and configurations other than those covered by ANSI B 1.1, ANSI B 1.13M, ANSI B 18.2.2, and B 18.2.4.6M are not subject to the proof load test.

8.2.2 *Number of Tests*:

8.2.2.1 The manufacturer shall test the number of nuts specified in 8.1.2.1 following all production heat treatments. Nuts that would require a proof load in excess of 160 000 lb/f or 705 kN may be furnished on the basis of minimum hardness requirements. Testing of nuts requiring a proof load in excess of 160 000 lb/f or 705 kN is covered in Supplementary Requirements S1 amd S4.

8.2.3 *Test Method*—The test shall be run using a threaded mandrel or a test bolt in accordance with Specification A 962/A 962M.

8.3 *Cone Proof Load Test:*

8.3.1 *Requirements*—This test shall be performed only when visible surface discontinuities become a matter of issue between the manufacturer and the purchaser. Nuts in the size range ¼ to 1½ in. inclusive and M6 to M36 inclusive shall be proof load tested. Nuts not in this size range and all types of Grade 8 nuts are not subject to this test. Also, nuts manufactured to dimensions and configurations other than those covered by Specification A 962/A 962M, ANSI B 1.1, ANSI

[5] An underline as a marking requirement for grades 2HM and 7M has been removed but is permitted.

TABLE 2 Hardness Requirements[A]

Grade and Type	Completed Nuts			Sample Nut after Treatment as in 8.1.5	
	Brinell Hardness	Rockwell Hardness		Brinell Hardness, min	Rockwell Hardness B Scale, min
		C Scale	B Scale		
1	121 min	...	70 min	121	70
2	159 to 352	...	84 min	159	84
2H to 1½ in. or M36, incl	248 to 327	24 to 35	...	179	89
2H over 1½ in. or M36	212 to 327	35 max	95 min	147	79
2HM and 7M	159 to 235	...	84 to 99	159	84
3, 4, 7, and 16	248 to 327	24 to 35	...	201	94
6 and 6F	228 to 271	20 to 28	...	...	...
8, 8C, 8M, 8T, 8F, 8P, 8N, 8MN, 8LN, 8MLN, 8MLCuN, and 9C	126 to 300	32 max	60 min	...	...
8A, 8CA, 8MA, 8TA, 8FA, 8PA, 8NA, 8MNA, 8LNA, 8MLNA, 8MLCuNA, and 9CA	126 to 192	...	60 to 90	...	...
8R, 8RA, 8S, and 8SA	183 to 271	25 max	88 min	...	...

[A] Where ellipses (...) appear in this table there is no requirement.

FOR INTERNAL REFERENCE ONLY

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TABLE 3 Proof Load Using Threaded Mandrel — Inch Series

NOTE 1—Proof loads are not design loads.

Nominal Size, in.	Threads per Inch	Stress Area in.²	Proof Load, lbf[A]					
			Grade 1		Grades 2, 2HM, 6, 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[E]	Heavy Hex[F]	Hex[G]
¼	20	0.0316	4 130	3 820	4 770	4 300	5 570	4 770
5⁄16	18	0.0524	6 810	6 290	7 860	7 070	9 170	7 860
⅜	16	0.0774	10 080	9 300	11 620	10 460	13 560	11 620
7⁄16	14	0.1063	13 820	12 760	15 940	14 350	18 600	15 940
½	13	0.1419	18 450	17 030	21 280	19 160	24 830	21 280
9⁄16	12	0.182	23 660	21 840	27 300	24 570	31 850	27 300
⅝	11	0.226	29 380	27 120	33 900	30 510	39 550	33 900
¾	10	0.334	43 420	40 080	50 100	45 090	58 450	50 100
⅞	9	0.462	60 060	55 440	69 300	62 370	80 850	69 300
1	8	0.606	78 780	72 720	90 900	81 810	106 000	90 900
1⅛	8	0.790	102 700	94 800	118 500	106 700	138 200	118 500
1¼	8	1.000	130 000	120 000	150 000	135 000	175 000	150 000
1⅜	8	1.233	160 200	148 000	185 000	166 500	215 800	185 000
1½	8	1.492	194 000	170 040	223 800	201 400	261 100	223 800

			All Types of Grade 8, Grades 9C and 9CA	
			Heavy Hex[H]	Hex[I]
¼	20	0.0316	2 540	2 380
5⁄16	18	0.0524	4 190	3 930
⅜	16	0.0774	6 200	5 810
7⁄16	14	0.1063	8 500	7 970
½	13	0.1419	11 350	10 640
9⁄16	12	0.182	14 560	13 650
⅝	11	0.226	18 080	16 950
¾	10	0.334	26 720	25 050
⅞	9	0.462	36 960	34 650
1	8	0.606	48 480	45 450
1⅛	8	0.790	63 200	59 250
1¼	8	1.000	80 000	75 000
1⅜	8	1.233	98 640	92 450
1½	8	1.492	119 360	111 900

[A] See limit for proof load test in 8.2.2.1. The proof load for jam nuts shall be 46 % of the tabulated load.
[B] Based on proof stress of 130 000 psi.
[C] Based on proof stress of 120 000 psi.
[D] Based on proof stress of 150 000 psi.
[E] Based on proof stress of 135 000 psi.
[F] Based on proof stress of 175 000 psi.
[G] Based on proof stress of 150 000 psi.
[H] Based on proof stress of 80 000 psi.
[I] Based on proof stress of 75 000 psi.

B 1.13M, ANSI B 18.2.2, and ANSI B 18.2.4.6M are not subject to the cone proof load test. The cone proof load applied shall be determined in accordance with the Cone Proof Load requirements in Specification A 962/A 962M (tables or formulae or both) based upon the proof stresses shown in Table 5 and Table 6 of Specification A 194/A 194M.

8.3.2 *Number of Tests*—The manufacturer shall sample and test the number of nuts specified in 8.1.2.1. The lot shall be considered acceptable if the sample nut(s) withstand(s) application of the cone proof load without failure.

9. Dimensions

9.1 Nuts shall be hexagonal in shape, and in accordance with the dimensions for the hex or heavy hex series, as required, by ANSI B 18.2.2 and ANSI B 18.2.4.6M. Unless otherwise specified, the American National Standard Heavy Hex Series shall be used and nuts shall be either double chamfered or have a machined or forged washer face, at the option of the manufacturer, and, conform to the angularity requirements of ANSI B 18.2.2 and ANSI B 18.2.4.6M.

9.2 Unless otherwise specified, threads shall be in accordance with ANSI B 1.1 or ANSI B 1.13M, and shall be gaged in accordance with ANSI B 1.2 and ANSI B 1.13M as described in 9.2.1 and 9.2.2.

9.2.1 Nuts up to and including 1 in. nominal size shall be UNC Series Class 2B fit. Metric nuts up to and including M24 nominal size shall be coarse thread series tolerance 6H.

TABLE 4 Proof Load Using Threaded Mandrel — Metric

NOTE 1—Proof loads are not design loads.

Nominal Size, mm	Threads Pitch	Stress Area mm²	Proof Load, kN[A]					
			Grade 1		Grades 2, 2HM, 6, 6F, 7M		Grades 2H, 3, 4, 7, 16	
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[E]	Heavy Hex[F]	Hex[G]
M6	1.0	20.1	18.0	16.6	20.8	18.7	29.2	20.8
M8	1.25	36.6	32.8	30.2	37.9	34.0	44.1	37.9
M10	1.50	58.0	51.9	47.9	60.0	53.9	69.9	60.0
M12	1.75	84.3	75.5	69.5	87.3	78.4	101.6	87.3
M14	2.0	115.0	102.9	94.9	119.0	107.0	138.6	119.0
M16	2.0	157.0	140.5	129.5	162.5	146.0	189.2	162.5
M20	2.5	245.0	219.3	202.1	253.6	227.8	295.2	253.6
M22	2.5	303.0	271.2	249.9	313.6	281.8	365.1	313.6
M24	3.0	353.0	315.9	291.2	365.4	328.3	425.4	365.4
M27	3.0	459.0	411.0	378.7	475.1	426.9	553.4	475.1
M30	3.5	561.0	502.1	462.8	580.6	521.7	676.0	580.6
M36	4.0	817.0	731.2	674.0	845.6	759.8	984.5	845.6

Nominal Size, mm	Thread Pitch	All Types of Grade 8, and Grades 9C and 9CA		
		Stress Area, mm²	Heavy Hex[H]	Hex[I]
M6	1.0	20.1	11.1	10.4
M8	1.25	36.6	20.1	18.8
M10	1.50	58.0	31.9	29.9
M12	1.75	84.3	46.4	43.4
M14	2.0	115.0	63.3	59.2
M16	2.0	157.0	86.4	80.9
M20	2.5	245.0	134.8	126.2
M22	2.5	303.0	166.7	156.0
M24	3.0	353.0	194.2	181.8
M27	3.0	459.0	252.5	236.4
M30	3.5	561.0	308.6	288.9
M36	4.0	817.0	449.4	420.8

[A] See limit for proof load test in 8.2.2.1. The proof load for jam nuts shall be 46 % of the tabulated load.
[B] Based on proof stress of 895 MPa.
[C] Based on proof stress of 825 MPa.
[D] Based on proof stress of 1035 MPa.
[E] Based on proof stress of 930 MPa.
[F] Based on proof stress of 1205 MPa.
[G] Based on proof stress of 1035 MPa.
[H] Based on proof stress of 550 MPa.
[I] Based on proof stress of 515 MPa.

TABLE 5 Proof Stress Using 120° Hardened Steel Cone — Inch

Type	Proof Stress – psi, Minimum		
	Grade 1	Grades 2, 2HM, 6, 6F & 7M	Grades 2H 3, 4, 7, & 16
Hex	120 000	135 000	150 000
Heavy Hex	130 000	150 000	175 000

TABLE 6 Proof Stress Using 120° Hardened Steel Cone — Metric

Type	Proof Stress – MPa, Minimum		
	Grade 1	Grades 2, 2HM, 6, 6F & 7M	Grades 2H 3, 4, 7, & 16
Hex	825	930	1035
Heavy Hex	895	1035	1205

9.2.2 Nuts over 1 in. nominal size shall be either UNC Series Class 2B fit or 8 UN Series Class 2B fit. Unless otherwise specified, the 8 UN series shall be furnished. Metric nuts over M24 nominal size shall be coarse thread series tolerance 6H.

10. Workmanship, Finish, and Appearance

10.1 Nuts shall be free of defects and shall be good commercial finish.

10.2 If visible surface imperfections in size ¼ through 1½ in. and M6 through M36 and in any grade other than Grade 8 become a matter of issue between the manufacturer and the purchaser, the cone proof load test described in 8.3 shall be employed.

10.3 If a scale-free bright finish is required, this shall be specified on the purchase order.

11. Retests

11.1 Provisions for retests by the purchaser and his representative are specified in Supplementary Requirement S2.

12. Certification

12.1 The producer of nuts shall furnish a certification to the purchaser or his representative showing the results of the chemical analysis, macroetch examination (Carbon and Alloy Steels Only), mechanical tests, and the minimum tempering temperature for nuts of Grades 2H, 2HM, 3, 4, 6, 6F, 7, and 7M.

12.2 Certification shall also include at least the following:

12.2.1 A statement that the fasteners were manufactured, sampled, tested and inspected in accordance with the specification and any supplementary requirements or other requirements designated in the purchase order or contract and was found to meet those requirements.

12.2.2 The specification number, year date, and identification symbol.

13. Product Marking

13.1 All nuts shall bear the manufacturer's identification mark.

13.2 Nuts shall be legibly marked on one face to indicate the grade and process of the manufacturer, as presented in Table 7. Marking of wrench flats or bearing surfaces is not permitted unless agreed upon between manufacturer and purchaser.

13.3 For purposes of identification marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

14. Keywords

14.1 bolting; chemical analysis; coated; marking on fasteners; plated

TABLE 7 Marking of Nuts[A]

Grade and Type	Nuts Hot-Forged or Cold-Punched	Nuts Machined from Bar Stock	Nuts Manufactured in Accordance with 6.6
1	1	1B	...
2	2	2B	...
2H[B]	2H	2HB	...
2HM[B]	2HM	2HMB	...
3	3	3B	...
4	4	4B	...
4L[C]	4L	4BL	...
6	6	6B	...
6F	6F	6FB	...
7	7	7B	...
7L[C]	7L	7BL	...
7M[B]	7M	7MB	...
8	8	8B	8A
8C	8C	8CB	8CA
8M	8M	8MB	8MA
8T	8T	8TB	8TA
8F	8F	8FB	8FA
8P	8P	8PB	8PA
8N	8N	8NB	8NA
8MN	8MN	8MNB	8MNA
8R	8R	8RB	8RA
8S	8S	8SB	8SA
8LN	8LN	8LNB	8LNA
8MLN	8MLN	8MLNB	8MLNA
8MLCuN	8MLCuN	8MLCuNB	8MLCuNA
9C	9C	9CB	9CA
16	16	16B	

[A] Where ellipses (...) appear in this table there is no requirement.
[B] The letters H and M indicate heat-treated nuts (see Section 6).
[C] See Supplementary Requirement S3.

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall be applied only when specified by the purchaser in the inquiry, contract, or order. Details of these supplementary requirements shall be agreed upon in writing by the manufacturer and purchaser. Supplementary requirements shall in no way negate any requirement of the specification itself.

S1. Strain-Hardened Austenitic Steel Nuts

S1.1 Strain hardened Grades 8, 8C, 8T, 8M, 8F, 8P, 8N, or 8MN nuts may be specified. When Supplementary Requirement S1 is invoked in the order, nuts shall be machined from cold drawn bars or shall be cold forged to shape. No subsequent heat treatment shall be performed on the nuts. Nuts made in accordance with this requirement shall be proof load tested in accordance with 8.2.2.1 and shall withstand the proof load specified in Table 8 and Table 9. Testing nuts requiring proof loads over 160 000 lbf or 705 kN is only required when Supplementary Requirement S4 is invoked. The hardness limits of Table 2 do not apply to strain hardened nuts. Nuts

TABLE 8 Proof Load Testing of Strain Hardened Nuts Using Threaded Mandrel — Inch Series

NOTE 1—Proof loads are not design loads.

			Proof Load, lbf[A]			
Nominal Size, in.	Threads per in.	Stress Area, in.^{2}	Grade 8M (strain hardened)	Grade 8M (strain hardened)	All Other Types of Grade 8 (strain hardened)	All Other Types of Grade 8 (strain hardened)
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[B]
¼	20	0.0316	3 480	3 160	3 950	3 480
5⁄16	18	0.0523	5 760	5 240	6 550	5 760
⅜	16	0.0774	8 510	7 740	9 675	8 510
7⁄16	14	0.1063	11 690	10 630	13 290	11 690
½	13	0.1419	15 610	14 190	17 740	15 610
9⁄16	12	0.182	20 020	18 200	22 750	20 020
⅝	11	0.226	24 860	22 600	28 250	24 860
¾	10	0.334	36 740	33 400	41 750	36 740
⅞	9	0.462	46 200	41 580	53 130	46 200
1	8	0.606	60 600	54 540	69 690	60 600
1⅛	8	0.790	75 050	67 150	82 950	75 050
1¼	8	1.000	95 000	85 000	105 000	95 000
1⅜	8	1.233	110 970	98 640	123 300	110 970
1½	8	1.492	134 280	119 360	149 200	134 280

[A] The proof load for jam nuts shall be 46 % of the tabulated value.
[B] Based on proof stress of 110 000 psi up to ¾ in.; 100 000 psi ⅞ to 1 in.; 95 000 psi 1⅛ to 1¼ in.; 90 000 psi 1⅜ to 1½ in.
[C] Based on proof stress of 100 000 psi up to ¾ in.; 90 000 psi ⅞ to 1 in.; 85 000 psi 1⅛ to 1¼ in.; 80 000 psi 1⅜ to 1½ in.
[D] Based on proof stress of 125 000 psi up to ¾ in.; 115 000 psi ⅞ to 1 in.; 105 000 psi 1⅛ to 1¼ in.; 100 000 psi 1⅜ to 1½ in.

TABLE 9 Proof Load Testing of Strain Hardened Nuts Using Threaded Mandrel — Metric

NOTE 1—Proof loads are not design loads.

			Proof Load, kN[A]			
Nominal Size, mm	Thread Pitch	Stress Area, mm^2	Grade 8M (strain hardened)	Grade 8M (strain hardened)	All Other Types of Grade 8 (strain hardened)	All Other Types of Grade 8 (strain hardened)
			Heavy Hex[B]	Hex[C]	Heavy Hex[D]	Hex[B]
M6	1.0	20.1	15.3	13.9	17.3	15.3
M8	1.25	36.6	27.8	25.3	31.3	27.8
M10	1.50	58.0	44.1	40.0	49.9	44.1
M12	1.75	84.3	64.1	58.2	72.5	64.1
M14	2.0	115.0	87.4	79.4	98.9	87.4
M16	2.0	157.0	119.3	108.3	135.0	119.3
M20	2.5	245.0	186.2	169.0	210.9	186.2
M22	2.5	303.0	209.0	187.9	240.9	209.0
M24	3.0	353.0	243.5	218.9	280.6	243.5
M27	3.0	459.0	300.6	268.5	332.7	300.6
M30	3.5	561.0	367.5	328.2	406.7	367.5
M36	4.0	817.0	506.5	449.4	563.7	506.5

[A] The proof load for jam nuts shall be 46 % of the tabulated value.
[B] Based on proof stress of 760 MPa up to M20 mm; 690 MPa M22 to M24 mm; 655 MPa M27 to M30; and 620 MPa for M36.
[C] Based on proof stress of 690 MPa up to M20 mm; 620 MPa M22 to M24 mm; 585 MPa M27 to M30; and 550 MPa for M36.
[D] Based on proof stress of 860 MPa up to M20 mm; 795 MPa M22 to M24 mm; 725 MPa M27 to M30 mm; and 690 MPa for M36.

made in accordance with this requirement shall be marked with the Grade symbol underlined.

S2. Retests by Purchaser's Representative

S2.1 The purchaser's representative may select two nuts per keg (200-lb unit [90-kg]) for sizes ⅝ in. and M16 and smaller, one nut per keg for sizes over ⅝ in. and M16 up to and including 1½ in. and M36, and one nut per every two kegs for sizes larger than 1½ in. and M36, which shall be subjected to the tests specified in Section 8.

S3. Low-Temperature Requirements for Grade 4, Grade 7 or Grade 7M Nuts

S3.1 When low-temperature requirements are specified for Grade 4 or Grade 7 nuts, the Charpy test procedures and requirements as defined in Specification A 320/A 320M for

Grade L7 shall apply. When low-temperature requirements are specified for Grade 7M nuts, the Charpy test procedures and requirements as defined in Specification A 320/A 320M for Grade L7M shall apply. Depending on the size of nuts, separate test samples of the same heat may be required and shall be processed through heat treatment with the nuts for which the test is to apply. Impact testing is not required when the bar stock or nut is smaller than ⅝ in. [16 mm] in diameter.

S3.2 An" L" shall be added to the marking, as shown in Table 7, for nuts so tested.

S4. Proof Load Tests of Large Nuts

S4.1 Proof load testing of nuts requiring proof loads of over 160 000 lbf or 705 kN is required. Testing shall be performed in accordance with 8.2 to the loads required in Table 10 and Table 11. The maximum load will be based entirely on the equipment available.

S5. Control of Product by Heat Number

S5.1 When control of nuts by actual heat analysis is required and this supplementary requirement is specified, the manufacturer shall identify the completed nuts in each shipment by the actual heat number. When this supplementary requirement is specified, a certificate including the results of the actual production tests of each test lot together with the heat chemical analysis shall be furnished by the manufacturer.

S6. Grain Size Requirements for Non H Grade Austenitic Steels Used Above 1000 °F

S6.1 For design metal temperatures above 1000 °F [540 °C], the material shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E 112. The grain size so determined shall be reported on the Certificate of Test.

S7. Coating on Nuts

S7.1 It is the purchaser's responsibility to specify in the purchase order all information required by the coating facility. Examples of such information may include but are not limited to the following:

S7.1.1 Reference to the appropriate coating specification and type, thickness, location, modification to dimensions, and hydrogen embrittlement relief.

NOTE S7.1—Modification of thread dimensions may result in loss of load carrying ability.

S7.1.2 Reference to Specifications A 153/A 153M, B 695, B 696, B 766, F 1941, Test Method F 1940, or other standards.

S8. Marking Coated Nuts

S8.1 Nuts coated with zinc shall have an asterisk (*) marked after the grade symbol. Nuts coated with cadmium shall have a plus sign (+) marked after the grade symbol.

TABLE 10 Proof Load for Large Heavy Hex Nuts — Inch[A]

Nominal Size, in.	Threads per in.	Stress Area, in.^{2}	Proof Load, lbf[B]		
			Grade 1 Heavy Hex	Grades 2, 2HM, 6, 6F, 7M Heavy Hex	Grades 2H, 3, 4, 7, 16 Heavy Hex
1⅝	8	1.78	231 400	267 000	311 500
1¾	8	2.08	270 400	312 000	364 000
1⅞	8	2.41	313 300	361 500	421 800
2	8	2.77	360 100	415 500	484 800
2¼	8	3.56	462 800	534 000	623 000
2½	8	4.44	577 200	666 000	777 000
2¾	8	5.43	705 900	814 500	950 250

[A] ANSI B 18.2.2 in the size range over 1½ in. provides dimensions only for heavy hex nuts. Refer to 8.3.1.

[B] Proof loads for nuts of larger dimensions or other thread series may be calculated by multiplying the thread stress area times the proof stress in the notes to Table 3 or Table 8. The proof load for jam nuts shall be 46 % of the tabulated load.

TABLE 11 Proof Load for Large Heavy Hex Nuts — Metric[A]

Nominal Size, mm	Thread Pitch	Stress Area, mm²	Proof Load, kN[B]		
			Grade 1 Heavy Hex	Grades 2, 2HM, 6, 6F, 7M Heavy Hex	Grades 2H, 3, 4, 7, 16 Heavy Hex
M42	4.5	1120	1002.4	1159.2	1349.6
M48	5	1470	1315.7	1521.4	1771.4
M56	5.5	2030	1816.9	2101.0	2446.2
M64	6	2680	2398.6	2773.8	3229.4
M72	6	3460	3096.7	3581.1	4169.3

[A] ANSI B 18.2.4.6M in the size range over M36 provides dimensions only for heavy hex nuts. Refer to 7.3.1.

[B] Proof loads for nuts of larger dimensions or other thread series may be calculated by multiplying the thread stress area times the proof stress in the notes to Table 4 or Table 9. The proof load for jam nuts shall be 46 % of the tabulated load.

APPENDIXES

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar, so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening. Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined.

X2. COATINGS AND APPLICATION LIMITS

X2.1 Use of coated fasteners at temperatures above approximately one-half the melting point (Fahrenheit or Celsius) of the coating is not recommended unless consideration is given to the potential for liquid and solid metal embrittlement, or both. The melting point of elemental zinc is approximately 780 °F [415 °C]. Therefore, application of zinc coated fasteners should be limited to temperatures less than 390 °F [210 °C]. The melting point of cadmium is approximately 600 °F [320 °C]. Therefore, application of cadmium coated fasteners should be limited to temperatures less than 300 °F [160 °C].

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 07b, that may impact the use of this specification. (Approved April 1, 2008)

(*1*) Added Nitrogen for Grades 8T and 8TA in Table 1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 07a, that may impact the use of this specification. (Approved December 1, 2007)

(*1*) Added Note S7.1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 07, that may impact the use of this specification. (Approved March 1, 2007)

(*1*) Added reference to Test Method F 1940 in S7.1.2.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 194/A 194M – 06a, that may impact the use of this specification. (Approved February 1, 2007)

(*1*) Revised cone proof load test requirements to reference recent changes to Specification A 962/A 962M and Test Methods and Definitions A 370.

Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications[1]

This standard is issued under the fixed designation A 193/A 193M; 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*

1.1 This specification[2] covers alloy and stainless steel bolting material for pressure vessels, valves, flanges, and fittings for high temperature or high pressure service, or other special purpose applications. The term *bolting material* as used in this specification covers bars, bolts, screws, studs, stud bolts, and wire. Bars and wire shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be carbide solution treated or carbide solution treated and strain-hardened. When strain hardened austenitic steel is ordered, the purchaser should take special care to ensure that Appendix X1 is thoroughly understood.

1.2 Several grades are covered, including ferritic steels and austenitic stainless steels designated B5, B8, and so forth. Selection will depend upon design, service conditions, mechanical properties, and high temperature characteristics.

NOTE 1—The committee formulating this specification has included fifteen steel types that have been rather extensively used for the present purpose. Other compositions will be considered for inclusion by the committee from time to time as the need becomes apparent.

NOTE 2—For grades of alloy-steel bolting material suitable for use at the lower range of high temperature applications, reference should be made to Specification A 354.

NOTE 3—For grades of alloy-steel bolting material suitable for use in low temperature applications, reference should be made to Specification A 320/A 320M.

1.3 Nuts for use with this bolting material are covered in Section 14.

1.4 Supplementary Requirements S1 through S10 are provided for use when additional tests or inspection are desired. These shall apply only when specified in the purchase order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable *M* specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 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.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
A 320/A 320M Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service
A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
A 788/A 788M Specification for Steel Forgings, General Requirements
A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
B 696 Specification for Coatings of Cadmium Mechanically Deposited
B 766 Specification for Electrodeposited Coatings of Cadmium

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved March 1, 2007. Published April 2007. Originally approved in 1936. Last previous edition approved in 2006 as A 193/A 193M-06a.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-193 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.

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

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials
E 112 Test Methods for Determining Average Grain Size
E 139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
E 150 Recommended Practice for Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of Rapid Heating and Short Times[4]
E 151 Recommended Practice for Tension Tests of Metallic Materials at Elevated Temperatures With Rapid Heating and Conventional or Rapid Strain Rates[4]
E 292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials
E 328 Test Methods for Stress Relaxation for Materials and Structures
E 566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals
E 709 Guide for Magnetic Particle Examination
E 606 Practice for Strain-Controlled Fatigue Testing
F 1940 Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners
F 1941 Specification for Electrodeposited Coatings on Threaded Fasteners (Unified Inch Screw Threads (UN/UNR))

2.2 *ANSI Standards:*[5]
B1.1 Screw Threads
B18.2.1 Square and Hex Bolts and Screws
B18.2.3.1M Metric Hex Cap Screws
B18.3 Hexagon Socket and Spline Socket Screws
B18.3.1M Metric Socket Head Cap Screws

2.3 *AIAG Standard:*[6]
AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

3. General Requirements and Ordering Information

3.1 The inquiry and orders shall include the following, as required, to describe the desired material adequately:

3.1.1 Heat-treated condition (that is, normalized and tempered, or quenched and tempered, for the ferritic materials, and carbide solution treated (Class 1), carbide solution treated after finishing (Class 1A), and carbide solution treated and strain-hardened (Classes 2, 2B and 2C), for the austenitic stainless steels; Classes 1B and 1C apply to the carbide solution-treated nitrogen-bearing stainless steels; Class 1D applies to material carbide solution treated by cooling rapidly from the rolling temperature),

3.1.2 Description of items required (that is, bars, bolts, screws, or studs),

3.1.3 Nuts, if required by purchaser, in accordance with 14.1,

3.1.4 Supplementary requirements, if any, and

3.1.5 Special requirements, in accordance with 7.3, 7.5.1, 11.2, 15.1, and 16.1.

3.2 *Coatings*—Coatings are prohibited unless specified by the purchaser (See Supplementary Requirement S13). When coated fasteners are ordered the purchaser should take special care to ensure that Appendix X2 is thoroughly understood.

4. Common Requirements

4.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A 962/A 962M, this specification shall prevail.

5. Manufacture (Process)

5.1 The steel shall be produced by any of the following processes: open-hearth, basic-oxygen, electric-furnace, or vacuum-induction melting (VIM). The molten steel may be vacuum-treated prior to or during pouring of the ingot or strand casting.

5.2 *Quality*—See Specification A 962/A 962M for requirements.

6. Discard

6.1 A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

7. Heat Treatment

7.1 Ferritic steels shall be properly heat treated as best suits the high temperature characteristics of each grade. Immediately after rolling or forging, the bolting material shall be allowed to cool to a temperature below the cooling transformation range. The materials which are to be furnished in the liquid-quenched condition shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a *quenching charge*) and quenched in a liquid medium under substantially uniform conditions for each quenching charge. Use of water quenching is prohibited for any ferritic grade when heat treatment is part of the fastener manufacturing process. This prohibition does not apply to heat treated bar or to fasteners machined therefrom. The materials that are to be furnished in the normalized or air-quenched condition shall be reheated to the proper temperature to refine the grain and cooled uniformly in air to a temperature below the transformation temperature range. The material, whether liquid-quenched or normalized, shall then be uniformly reheated for tempering. The minimum tempering temperature shall be as specified in Table 2 and Table 3.

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[4] Withdrawn.
[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.
[6] Available from Automotive Industry Action Group, 26200 Lahser, Suite 200, Southfield, MI 48034.

TABLE 1 Chemical Requirements (Composition, percent)[A]

Type	Ferritic Steels			
Grade	B5		B6 and B6X	
Description.	5% Chromium		12 % Chromium	
UNS Designation			S41000 (410)	
	Range	Product Variation, Over or Under[B]	Range	Product Variation Over or Under[B]
Carbon	0.10 min	0.01 under	0.08–0.15	0.01 over
Manganese, max	1.00	0.03 over	1.00	0.03 over
Phosphorus, max	0.040	0.005 over	0.040	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00 max	0.05 over	1.00 max	0.05 over
Chromium	4.0–6.0	0.10	11.5–13.5	0.15
Molybdenum	0.40–0.65	0.05	. . .	. . .

Type	Ferritic Steels			
Grade	B7, B7M		B16	
Description	Chromium-Molybdenum[C]		Chromium-Molybdenum-Vanadium	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon	0.37–0.49[D]	0.02	0.36–0.47	0.02
Manganese	0.65–1.10	0.04	0.45–0.70	0.03
Phosphorus, max	0.035	0.005 over	0.035	0.005 over
Sulfur, max	0.040	0.005 over	0.040	0.005 over
Silicon	0.15–0.35	0.02	0.15–0.35	0.02
Chromium	0.75–1.20	0.05	0.80–1.15	0.05
Molybdenum	0.15–0.25	0.02	0.50–0.65	0.03
Vanadium	. . .	. . .	0.25–0.35	0.03
Aluminum, max %[E]	. . .	. . .	0.015	. . .

Type	Austenitic Steels,[F] Classes 1, 1A, 1D, and 2							
Grade . .	B8, B8A		B8C, B8CA		B8M, B8MA, B8M2, B8M3		B8P, B8PA	
UNS Designation	S30400 (304)		S34700 (347)		S31600 (316)		S30500	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.08	0.01 over	0.12	0.01 over
Manganese, max	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.030	0.005 over	0.030	0.005 over
Silicon, max	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over
Chromium	18.0–20.0	0.20	17.0–19.0	0.20	16.0–18.0	0.20	17.0–19.0	0.20
Nickel	8.0–11.0	0.15	9.0–12.0	0.15	10.0–14.0	0.15	11.0–13.0	0.15
Molybdenum	. . .	. . .	. . .	. . .	2.00–3.00	0.10	. . .	. . .
Columbium + tantalum	. . .	. . .	10 x carbon content, min; 1.10 max	0.05 under	. . .	. . .	. . .	. . .

Type	Austenitic Steels,[F] Classes 1A, 1B, 1D, and 2					
Grade	B8N, B8NA		B8MN, B8MNA		B8MLCuN, B8MLCuNA	
UNS Designation	S30451 (304N)		S31651 (316N)		S31254	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.020	0.005 over
Manganese, max	2.00	0.04 over	2.00	0.04 over	1.00	0.03 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.030	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.010	0.002 over
Silicon, max	1.00	0.05 over	1.00	0.05 over	0.80	0.05 over
Chromium	18.0–20.0	0.20	16.0–18.0	0.20	19.5–20.5	0.20
Nickel	8.0–11.0	0.15	10.0–13.0	0.15	17.5–18.5	0.15
Molybdenum	. . .	. . .	2.00–3.00	0.10	6.0–6.5	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01	0.18–0.22	0.02
Copper	. . .	. . .	. . .	. . .	0.50–1.00	. . .

TABLE 1 *Continued*

Type	Austenitic Steels[F], Classes 1, 1A, and 2	
Grade	B8T, B8TA	
UNS Designation	S32100 (321)	
	Range	Product Variation, Over or Under[B]
Carbon, max	0.08	0.01 over
Manganese, max	2.00	0.04 over
Phosphorus, max	0.045	0.010 over
Sulfur, max	0.030	0.005 over
Silicon, max	1.00	0.05 over
Chromium	17.0–19.0	0.20
Nickel	9.0–12.0	0.15
Titanium	5 x (C + N) min, 0.70 max[G]	0.05 under

Type	Austenitic Steels[F], Classes 1C and 1D			
Grade	B8R, B8RA		B8S, B8SA	
UNS Designation	S20910		S21800	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.06	0.01 over	0.10	0.01 over
Manganese	4.0–6.0	0.05	7.0–9.0	0.06
Phosphorus, max	0.045	0.005 over	0.060	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00 max	0.05 over	3.5–4.5	0.15
Chromium	20.5–23.5	0.25	16.0–18.0	0.20
Nickel	11.5–13.5	0.15	8.0–9.0	0.10
Molybdenum	1.50–3.00	0.10	. . .	. . .
Nitrogen	0.20–0.40	0.02	0.08–0.18	0.01
Columbium + tantalum	0.10–0.30	0.05	. . .	. . .
Vanadium	0.10–0.30	0.02	. . .	. . .

Type	Austenitic Steels[F], Classes 1, 1A and 1D			
Grade	B8LN, B8LNA		B8MLN, B8MLNA	
UNS Designation	S30453		S31653	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.030	0.005 over	0.030	0.005 over
Manganese	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00	0.05 over	1.00	0.05 over
Chromium	18.0–20.0	0.20	16.0–18.0	0.20
Nickel	8.0–11.0	0.15	10.0–13.0	0.15
Molybdenum	. . .	. . .	2.00–3.00	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01

[A] The intentional addition of Bi, Se, Te, and Pb is not permitted.

[B] Product analysis—Individual determinations sometimes vary from the specified limits on ranges as shown in the tables. The several determinations of any individual element in a heat may not vary both above and below the specified range.

[C] Typical steel compositions used for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H.

[D] For bar sizes over 3½ in. [90 mm], inclusive, the carbon content may be 0.50 %, max. For the B7M grade, a minimum carbon content of 0.28 % is permitted, provided that the required tensile properties are met in the section sizes involved; the use of AISI 4130 or 4130H is allowed.

[E] Total of soluble and insoluble.

[F] Classes 1 and 1D are solution treated. Classes 1, 1B, and some 1C (B8R and B8S) products are made from solution treated material. Class 1A (B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, and B8MNA) and some Class 1C (B9RA and B8SA) products are solution treated in the finished condition. Class 2 products are solution treated and strain hardened.

[G] Nitrogen content is to be reported for this grade.

TABLE 2 Mechanical Requirements — Inch Products

Grade	Diameter, in.	Minimum Tempering Temperature, °F	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
Ferritic Steels							
B5 4 to 6 % chromium	up to 4, incl	1100	100	80	16	50	. . .
B6 13 % chromium	up to 4, incl	1100	110	85	15	50	. . .
B6X 13 % chromium	up to 4, incl	1100	90	70	16	50	26 HRC
B7 Chromium-molybdenum	2½ and under	1100	125	105	16	50	321 HB or 35 HRC
	over 2½ to 4	1100	115	95	16	50	321 HB or 35 HRC
	over 4 to 7	1100	100	75	18	50	321 HB or 35 HRC
B7M[A] Chromium-molybdenum	4 and under	1150	100	80	18	50	235 HB or 99 HRB
	over 4 to 7	1150	100	75	18	50	235 BHN or 99 HRB
B16 Chromium-molybdenum-vanadium	2½ and under	1200	125	105	18	50	321 HB or 35 HRC
	over 2½ to 4	1200	110	95	17	45	321 HB or 35 HRC
	over 4 to 8	1200	100	85	16	45	321 HB or 35 HRC

Grade, Diameter, in.	Heat Treatment[B]	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
Austenitic Steels						
Classes 1 and 1D; B8, B8M, B8P, B8LN, B8MLN, all diameters	carbide solution treated	75	30	30	50	223 HB[C] or 96 HRB
Class 1: B8C, B8T, all diameters	carbide solution treated	75	30	30	50	223 HB[C] or 96HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA B8MLCuNA, all diameters	carbide solution treated in the finished condition	75	30	30	50	192 HB or 90 HRB
Classes 1B and 1D: B8N, B8MN, and B8MLCuN, all diameters	carbide solution treated	80	35	30	40	223 HB[C] or 96 HRB
Classes 1C and 1D: B8R, all diameters	carbide solution treated	100	55	35	55	271 HB or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	100	55	35	55	271 HB or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated	95	50	35	55	271 HB or 28 HRC
Classes 1C: B8SA, all diameters	carbide solution treated in the finished condition	95	50	35	55	271 HB or 28 HRC
Class 2: B8, B8C, B8P, B8T, and B8N,[D] ¾ and under	carbide solution treated and strain hardened	125	100	12	35	321 HB or 35 HRC
over ¾ to 1, incl		115	80	15	35	321 HB or 35 HRC
over 1 to 1¼ , incl		105	65	20	35	321 HB or 35 HRC
over 1¼ to 1½ , incl		100	50	28	45	321 HB or 35 HRC
Class 2: B8M, B8MN, B8MLCuN[D] ¾ and under	carbide solution treated and strain hardened	110	95	15	45	321 HB or 35 HRC
over ¾ to 1 incl		100	80	20	45	321 HB or 35 HRC
Over 1 to 1¼ , incl		95	65	25	45	321 HB or 35 HRC
over 1¼ to 1½ , incl		90	50	30	45	321 HB or 35 HRC
Class 2B: B8, B8M2[D] 2 and under	carbide solution treated and strain hardened	95	75	25	40	321 HB or 35 HRC

TABLE 2 *Continued*

Grade, Diameter, in.	Heat Treatment[B]	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
		Austenitic Steels				
over 2 to 2½ incl		90	65	30	40	321 HB or 35 HRC
over 2½ to 3 incl		80	55	30	40	321 HB or 35 HRC
Class 2C: B8M3[D] 2 and under	carbide solution treated and strain hardened	85	65	30	60	321 HB or 35 HRC
over 2		85	60	30	60	321 HB or 35 HRC

[A] To meet the tensile requirements, the Brinell hardness shall be over 200 HB (93 HRB).
[B] Class 1 is solution treated. Class 1A is solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement. Class 2 is solution treated and strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over ¾ in. in diameter.
[C] For sizes ¾ in. in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.
[D] For diameters 1½ and over, center (core) properties may be lower than indicated by test reports which are based on values determined at ½ radius.

TABLE 3 Mechanical Requirements —Metric Products

Class	Diameter, [mm]	Minimum Tempering Temperature, °C	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
			Ferritic Steels				
B5 4 to 6 % chromium	up to M100, incl	593	690	550	16	50	. . .
B6 13 % chromium	up to M100, incl	593	760	585	15	50	. . .
B6X 13 % chromium	up to M100, incl	593	620	485	16	50	26 HRC
B7 Chromium-molybdenum	M64 and under	593	860	720	16	50	321 HB or 35 HRC
	over M64 to M100	593	795	655	16	50	321 HB or 35 HRC
	over M100 to M180	593	690	515	18	50	321 HB or 35 HRC
B7M[A] Chromium-molybdenum	M100 and under	620	690	550	18	50	235 HB or 99 HRB
	over M100 to M180	620	690	515	18	50	235 BHN or 99 HRB
B16 Chromium-molybdenum-vanadium	M64 and under	650	860	725	18	50	321 HB or 35 HRC
	over M64 to M100	650	760	655	17	45	321 HB or 35 HRC
	over M100 to M180	650	690	585	16	45	321 HB or 35 HRC

Class Diameter, mm	Heat Treatment[B]	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
		Austenitic Steels				
Classes 1 and 1D; B8, B8M, B8P, B8LN, B8MLN, all diameters	carbide solution treated	515	205	30	50	223 HB[C] or 96 HRB
Class 1: B8C, B8T, all diameters	carbide solution treated	515	205	30	50	223 HB[C] or 96HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA B8MLCuNA, all diameters	carbide solution treated in the finished condition	515	205	30	50	192 HB or 90 HRB
Classes 1B and 1D: B8N, B8MN, and B8MLCuN, all diameters	carbide solution treated	550	240	30	40	223 HB[C] or 96 HRB
Classes 1C and 1D: B8R, all diameters	carbide solution treated	690	380	35	55	271 HB or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	690	380	35	55	271 HB or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated	655	345	35	55	271 HB or 28 HRC

TABLE 3 *Continued*

Class Diameter, mm	Heat Treatment[B]	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
		Austenitic Steels				
Classes 1C: B8SA, all diameters	carbide solution treated in the finished condition	655	345	35	55	271 HB or 28 HRC
Class 2: B8, B8C, B8P, B8T, and B8N,[D] M20 and under	carbide solution treated and strain hardened	860	690	12	35	321 HB or 35 HRC
over M20 to M24, incl		795	550	15	35	321 HB or 35 HRC
over M24 to M30, incl		725	450	20	35	321 HB or 35 HRC
over M30 to M36, incl		690	345	28	45	321 HB or 35 HRC
Class 2: B8M, B8MN, B8MLCuN,[D] M20 and under	carbide solution treated and strain hardened	760	655	15	45	321 HB or 35 HRC
over M20 to M24, incl		690	550	20	45	321 HB or 35 HRC
over M24 to M30, incl		655	450	25	45	321 HB or 35 HRC
over M30 to M36, incl		620	345	30	45	321 HB or 35 HRC
Class 2B: B8, B8M2,[D] M48 and under	carbide solution treated and strain hardened	655	515	25	40	321 HB or 35 HRC
over M48 to M64, incl		620	450	30	40	321 HB or 35 HRC
over M64 to M72, incl		550	380	30	40	321 HB or 35 HRC
Class 2C: B8M3,[D] M48 and under	carbide solution treated and strain hardened	585	450	30	60	321 HB or 35 HRC
over M48		585	415	30	60	321 HB or 35 HRC

[A] To meet the tensile requirements, the Brinell hardness shall be over 200 HB (93 HRB).
[B] Class 1 is solution treated. Class 1A is solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement. Class 2 is solution treated and strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over M20 mm in diameter
[C] For sizes M20 mm in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.
[D] For diameters M38 and over, center (core) properties may be lower than indicated by test reports which are based on values determined at ½ radius.

7.1.1 Quenched and tempered or normalized and tempered ferritic material that is subsequently cold drawn for dimensional control shall be stress-relieved after cold drawing. The minimum stress-relief temperature shall be 100 °F [55 °C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

7.2 Both B6 and B6X materials shall be held, at the tempering temperature for a minimum time of 1 h. Identification Symbol B 6X material may be furnished in the as-rolled-and-tempered condition. Cold working is permitted with the hardness limitation (26 HRC maximum) of Table 2 for the B 6X grade.

7.3 All austenitic stainless steels shall receive a carbide solution treatment (see 7.3.1-7.3.4 for specific requirements for each class). Classes 1, 1B, 1C (Grades B8R and B8S only), 2, 2B, and 2C can apply to bar, wire, and finished fasteners. Class 1A (all grades) and Class 1C (grades B8RA and B8SA only) can apply to finished fasteners. Class 1D applies only to bar and wire and finished fasteners that are machined directly from Class 1D bar or wire without any subsequent hot or cold working.

7.3.1 *Classes 1 and 1B, and Class 1C Grades B8R and B8S*—After rolling of the bar, forging, or heading, whether done hot or cold, the material shall be heated from ambient temperature and held a sufficient time at a temperature at which the chromium carbide will go into solution and then shall be cooled at a rate sufficient to prevent the precipitation of the carbide.

7.3.2 *Class 1D*—Rolled or forged Grades B8, B8M, B8P, B8LN, B8MLN, B8N, B8MN, B8R, and B8S bar shall be cooled rapidly immediately following hot working while the temperature is above 1750 °F [955 °C] so that grain boundary carbides are in solution. Class 1D shall be restricted to applications at temperatures less than 850 °F [455 °C].

7.3.3 *Class 1A and Class 1C Grades B8RA and B8SA*—Finished fasteners shall be carbide solution treated after all rolling, forging, heading, and threading operations are complete. This designation does not apply to starting material such as bar. Fasteners shall be heated from ambient temperature and held a sufficient time at a temperature at which the chromium carbide will go into solution and then shall be cooled at a rate sufficient to prevent the precipitation of the carbide.

7.3.4 *Classes 2, 2B, and 2C*—Material shall be carbide solution treated by heating from ambient temperature and holding a sufficient time at a temperature at which the chromium carbide will go into solution and then cooling at a rate sufficient to prevent the precipitation of the carbide. Following this treatment the material shall then be strain hardened to achieve the required properties.

NOTE 4—Heat treatment following operations performed on a limited portion of the product, such as heading, may result in non-uniform grain size and mechanical properties through the section affected.

7.4 If scale-free bright finish is required, this shall be specified in the purchase order.

7.5 B7 and B7M bolting material shall be heat treated by quenching in a liquid medium and tempering. For B7M bolting, the final heat treatment, which may be the tempering operation if conducted at 1150 °F [620 °C] minimum, shall be done after all machining and forming operations, including thread rolling and any type of cutting. Surface preparation for hardness testing, nondestructive evaluation, or ultrasonic bolt tensioning is permitted.

7.5.1 Unless otherwise specified, material for Grade B7 may be heat treated by the Furnace, the Induction or the Electrical Resistance method.

NOTE 5—It should be taken into consideration that stress-relaxation properties may vary from heat lot to heat lot or these properties may vary from one heat treating method to another. The purchaser may specify Supplementary Requirement S8, if stress-relaxation testing is desired.

7.6 Material Grade B16 shall be heated to a temperature range from 1700 to 1750 °F [925 to 955 °C] and oil quenched. The minimum tempering temperature shall be as specified in Table 2.

8. Chemical Composition

8.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 1.

8.2 The steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element. Furthermore, elements present in concentrations greater than 0.75 weight/% shall be reported.

9. Heat Analysis

9.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 8. The chemical composition thus determined shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 8. Should the purchaser deem it necessary to have the transition zone of two heats sequentially cast discarded, the purchaser shall invoke Supplementary Requirement S3 of Specification A 788.

10. Mechanical Properties

10.1 *Tensile Properties*:

10.1.1 *Requirements*—The material as represented by the tension specimens shall conform to the requirements prescribed in Table 2 at room temperature after heat treatment. Alternatively, stainless strain hardened headed fasteners (Class 2, 2B, and 2C) shall be tested full size after strain hardening to determine tensile strength and yield strength and shall conform to the requirements prescribed in Table 2. Should the results of full size tests conflict with results of tension specimen tests, full size test results shall prevail.

10.1.2 *Full Size Fasteners, Wedge Tensile Testing*—When applicable, see 13.1.3, headed fasteners shall be wedge tested full size and shall conform to the tensile strength shown in Table 2. The minimum full size breaking strength (lbf) for individual sizes shall be as follows:

$$Ts = UTS \times As \quad (1)$$

where:

Ts = wedge tensile strength,
UTS = tensile strength specified in Table 2, and
As = stress area, square inches, as shown in ANSI B1.1 or calculated as follows:

$$As = 0.785\,(D - (0.974/n))^2 \quad (2)$$

where:

D = nominal thread size, and
n = the number of threads per inch.

10.2 *Hardness Requirements*:

10.2.1 The hardness shall conform to the requirements prescribed in Table 2. Hardness testing shall be performed in accordance with either Specification A 962/A 962M or with Test Methods F 606.

10.2.2 *Grade B7M*—The maximum hardness of the grade shall be 235 HB or 99 HRB. The minimum hardness shall not be less than 200 HB or 93 HRB. Conformance to this hardness shall be ensured by testing the hardness of each stud or bolt by Brinell or Rockwell B methods in accordance with 10.2.1. The use of 100 % electromagnetic testing for hardness as an alternative to 100 % indentation hardness testing is permissible when qualified by sampling using indentation hardness testing. Each lot tested for hardness electromagnetically shall be 100 % examined in accordance with Practice E 566. Following electromagnetic testing for hardness a random sample of a minimum of 100 pieces of each heat of steel in each lot (as defined in 13.1.1) shall be tested by indentation hardness methods. All samples must meet hardness requirements to permit acceptance of the lot. If any one sample is outside of the specified maximum or minimum hardness, the lot shall be rejected and either reprocessed and resampled or tested 100 % by indentation hardness methods. Product that has been 100 % tested and found acceptable shall have a line under the grade symbol.

10.2.2.1 Surface preparation for indentation hardness testing shall be in accordance with Test Methods E 18. Hardness tests shall be performed on the end of the bolt or stud. When this is impractical, the hardness test shall be performed elsewhere.

11. Workmanship, Finish, and Appearance

11.1 Bolts, screws, studs, and stud bolts shall be pointed and shall have a workmanlike finish. Points shall be flat and chamfered or rounded at option of the manufacturer. Length of point on studs and stud bolts shall be not less than one nor more than two complete threads as measured from the extreme end parallel to the axis. Length of studs and stud bolts shall be measured from first thread to first thread.

11.2 Bolt heads shall be in accordance with the dimensions of ANSI B18.2.1 or ANSI B18.2.3.1M. Unless otherwise specified in the purchase order, the Heavy Hex Screws Series should be used, except the maximum body diameter and radius of fillet may be the same as for the Heavy Hex Bolt Series. The body diameter and head fillet radius for sizes of Heavy Hex Cap Screws and Bolts that are not shown in their respective tables in ANSI B18.2.1 or ANSI B18.2.3.1M may be that shown in the corresponding Hex Cap Screw and Bolt Tables respectively. Socket head fasteners shall be in accordance with ANSI B18.3 or ANSI B18.3.1M.

12. Retests

12.1 If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two additional tension tests shall be made from such lot, all of which shall conform to the requirements specified.

13. Test Specimens

13.1 *Number of Tests*—For heat-treated bars, one tension test shall be made for each diameter of each heat represented in each tempering charge. When heat treated without interruption in continuous furnaces, the material in a lot shall be the same heat, same prior condition, same size, and subjected to the same heat treatment. Not fewer than two tension tests are required for each lot containing 20 000 lb [9000 kg] or less. Every additional 10 000 lb [4500 kg] or fraction thereof requires one additional test.

13.1.1 For studs, bolts, screws, and so forth, one tension test shall be made for each diameter of each heat involved in the lot. Each lot shall consist of the following:

Diameter, in. [mm]	Lot Size
1⅛ [30] and under	1500 lb [780 kg] or fraction thereof
Over 1⅛ [30] to 1¾ [42], incl	4500 lb [2000 kg] or fraction thereof
Over 1¾ [42] to 2½ [64], incl	6000 lb [2700 kg] or fraction thereof
Over 2½ [64]	100 pieces or fraction thereof

13.1.2 Tension tests are not required to be made on bolts, screws, studs, or stud bolts that are fabricated from heat-treated bars furnished in accordance with the requirements of this specification and tested in accordance with 13.1, provided they are not given a subsequent heat treatment.

13.1.3 *Full Size Specimens, Headed Fasteners*—Headed fasteners 1½ in. in body diameter and smaller, with body length three times the diameter or longer, and that are produced by upsetting or forging (hot or cold) shall be subjected to full size testing in accordance with 10.1.2. This testing shall be in addition to tensile testing as specified in 10.1.1. The lot size shall be as shown in 13.1.1. Failure shall occur in the body or threaded section with no failure, or indications of failure, such as cracks, at the junction of the head and shank.

14. Nuts

14.1 Bolts, studs, and stud bolts shall be furnished with nuts, when specified in the purchase order. Nuts shall conform to Specification A 194/A 194M.

15. Rejection and Rehearing

15.1 Unless otherwise specified in the basis of purchase, any rejection based on product analysis shall be reported to the manufacturer within 30 days from the receipt of samples by the purchaser.

15.2 Material that shows defects subsequent to its acceptance at the place of manufacture shall be rejected, and the manufacturer shall be notified.

15.3 *Product Analysis*—Samples that represent rejected material shall be preserved for two weeks from the date of the test report. In the case of dissatisfaction with the results of the test, the manufacturer may make claim for a rehearing within that time.

16. Certification

16.1 The producer of the raw material or finished fasteners shall furnish a certification to the purchaser or his representative showing the results of the chemical analysis, macroetch examination (Carbon and Alloy Steels Only), and mechanical tests, and state the method of heat treatment employed.

16.2 Certification shall also include at least the following:

16.2.1 A statement that the material or the fasteners, or both, were manufactured, sampled, tested, and inspected in accordance with the specification and any supplementary requirements or other requirements designated in the purchase order or contract and was found to meet those requirements.

16.2.2 The specification number, year date, and identification symbol.

17. Product Marking

17.1 The marking symbol and manufacturer's identification symbol shall be applied to one end of studs ⅜ in. [10 mm] in diameter and larger and to the heads of bolts ¼ in. [6 mm] in diameter and larger. (If the available area is inadequate, the marking symbol may be placed on one end with the manufacturer's identification symbol placed on the other end.) The marking symbol shall be as shown in Table 4 and Table 5. Grade B7M, which has been 100 % evaluated in conformance with the specification, shall have a line under the marking symbol to distinguish it from B7M produced to previous specification revisions not requiring 100 % hardness testing.

17.2 For bolting materials, including threaded bars, furnished bundled and tagged or boxed, the tags and boxes shall carry the marking symbol for the material identification and the manufacturer's identification symbol or name.

17.3 For purposes of product marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

17.4 *Bar Coding*—In addition to the requirements in 17.1, 17.2, and 17.3, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG Standard B-5 02.00. If used on small items, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 hardness; heat treatment

TABLE 4 Marking of Ferritic Steels

Grade	Marking Symbol
B5	B5
B6	B6
B6X	B6X
B7	B7
B7M[A]	B7M <u>B7M</u>
B16	B16
B16 + Supplement S12	B16R

[A] For explanations, see 10.2.2 and 17.1.

TABLE 5 Marking of Austenitic Steels

Class	Grade	Marking Symbol
Class 1	B8	B8
	B8C	B8C
	B8M	B8M
	B8P	B8P
	B8T	B8T
	B8LN	B8F or B8LN
	B8MLN	B8G or B8MLN
Class 1A	B8A	B8A
	B8CA	B8B or B8CA
	B8MA	B8D or B8MA
	B8PA	B8H or B8PA
	B8TA	B8J or B8TA
	B8LNA	B8L or B8LNA
	B8MLNA	B8K or B8MLNA
	B8NA	B8V or B8MA
	B8MNA	B8W or B8MNA
	B8MLCuNA	B9K or B8MLCuNA
Class 1B	B8N	B8N
	B8MN	B8Y or B8MN
	B8MLCuN	B9J or B8MLCuN
Class 1C	B8R	B9A or B8R
	B8RA	B9B or B8RA
	B8S	B9D or B8S
	B8SA	B9F or B8SA
Class 1D	B8	B94
	B8M	B95
	B8P	B96
	B8LN	B97
	B8MLN	B98
	B8N	B99
	B8MN	B100
	B8R	B101
	B8S	B102
Class 2	B8	B8SH
	B8C	B8CSH
	B8P	B8PSH
	B8T	B8TSH
	B8N	B8NSH
	B8M	B8MSH
	B8MN	B8YSH
	B8MLCuN	B0JSH
Class 2B	B8M2	B9G or B8M2
	B8	B9
Class 2C	B8M3	B9H or B8M3

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order and in the Ordering Information, in which event the specified tests shall be made before shipment of the product.

S1. High Temperature Tests

S1.1 Tests to determine high temperature properties shall be made in accordance with Test Methods E 21, E 139, and E 292, and Practices E 150 and E 151.

S2. Charpy Impact Tests

S2.1 Charpy impact tests based on the requirements of Specification A 320/A 320M, Sections 6 and 7, shall be made as agreed between the manufacturer and the purchaser. When testing temperatures are as low as those specified in Specification A 320/A 320M, bolting should be ordered to that specification in preference to this specification.

S3. 100 % Hardness Testing of Grade B7M

S3.1 Each Grade B7M bolt or stud shall be tested for hardness by indentation method and shall meet the requirements specified in Table 2.

S4. Hardness Testing of Grade B16

S4.1 For bolts or studs 2½ in. [65 mm] or smaller, the hardness for Grade B16 shall be measured on or near the end of each bolt or stud using one of the methods prescribed in 10.2.1 for the Brinell or Rockwell C test. The hardness shall be in the range 253–319 HB or 25–34 HRC.

S5. Product Marking

S5.1 Marking and manufacturer's identification symbols shall be applied to one end of studs and to the heads of bolts of all sizes. (If the available area is inadequate, the marking symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) For bolts smaller than ¼ in. [6 mm] in diameter and studs smaller than ⅜ in. [10 mm] in diameter and for ¼ in. [6 mm] in diameter studs requiring more than a total of three symbols, the marking shall be a matter of agreement between the purchaser and the manufacturer.

S6. Stress Relieving

S6.1 A stress-relieving operation shall follow straightening after heat treatment.

S6.2 The minimum stress-relieving temperature shall be 100 °F [55 °C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

S7. Magnetic Particle Inspection

S7.1 Bars shall be magnetic particle examined in accordance with Guide E 709. Bars with indications of cracks or seams are subject to rejection if the indications extend more than 3 % of the diameter into the bar.

S8. Stress-Relaxation Testing

S8.1 Stress-Relaxation Testing, when required, shall be done in accordance with Test Methods E 328. The test shall be performed at 850 °F [454 °C] for a period of 100 h. The initial stress shall be 50 M psi [345 MPa]. The residual stress at 100 h shall be 17 M psi [117 MPa] minimum.

S9. Grain Size Requirements for Non H Grade Austenitic Steels Used Above 1000 °F

S9.1 For design metal temperatures above 1000 °F [540 °C], the material shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E 112. The grain size so determined shall be reported on the Certificate of Test.

S10. Hardness Testing of Class 2 Bolting Materials for ASME Applications

S10.1 The maximum hardness shall be Rockwell C35 immediately under the thread roots. The hardness shall be taken on a flat area at least ⅛ in. [3 mm] across, prepared by removing threads, and no more material than necessary shall be removed to prepare the flat areas. Hardness determinations shall be made at the same frequency as tensile tests.

S11. Thread Forming

S11.1 Threads shall be formed after heat treatment. Application of this supplemental requirement to grade B7M or the grades listed in 7.3.3 is prohibited.

S12. Stress Rupture Testing of Grade B16

S12.1 One test shall be made for each heat treat lot. Testing shall be conducted using a combination test bar in accordance with Test Methods E 292. Rupture shall occur in the smooth section of each test specimen. The test shall be conducted at 1100 °F [595 °C] and 20 ksi [140 MPa]. The test shall be continued until the sample ruptures. Rupture life shall be 25 h minimum. Testing is not required on material less than ½ in. [12 mm] thick.

S12.2 When a purchase order for fasteners invokes S12, the product marking supplied shall be "B16R."

S13. Coatings on Bolting Materials

S13.1 It is the purchaser's responsibility to specify in the purchase order all information required by the coating facility. Examples of such information may include but are not limited to the following:

S13.1.1 Reference to the appropriate coating specification and type, thickness, location, modification to dimensions, and hydrogen embrittlement relief.

S13.1.2 Reference to Specifications A 153/A 153M, B 695, B 696, B 766, or F 1941, Test Method F 1940, or other standards.

APPENDIXES

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars or wire to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle, and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening.

X1.2 Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined. The minimum bar size that can be used, however, is established by the configuration of the fastener so that the configuration can affect the strength of the fastener.

X1.3 For example, a stud of a particular alloy and size may be machined from a smaller diameter bar than a bolt of the same alloy and size because a larger diameter bar is required to accommodate the head of the bolt. The stud, therefore, is likely to be stronger than the same size bolt in a given alloy.

X2. COATINGS AND APPLICATION LIMITS

X2.1 Use of coated fasteners at temperatures above approximately one-half the melting point (Fahrenheit or Celsius) of the coating is not recommended unless consideration is given to the potential for liquid and solid metal embrittlement, or both. The melting point of elemental zinc is approximately 780 °F [415 °C]. Therefore, application of zinc-coated fasteners should be limited to temperatures less than 390 °F [210 °C]. The melting point of cadmium is approximately 600 °F [320 °C]. Therefore, application of cadmium-coated fasteners should be limited to temperatures less than 300 °F [160 °C].

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 193/A 193M – 06a, that may impact the use of this specification. (Approved March 1, 2007).

(*1*) Deleted the space between the S and the numbers in the UNS designations in Table 1.

(*2*) Added permissible product variations for B8MLCuN and B8MLCuNA in Table 1.

(*3*) Added the requirement to report nitrogen for S32100 and changed the order of the elements in Table 1 for this grade to be consistent with the other stainless grades.

(*4*) Corrected the metric yield strength for B16 M100 to M180 in Table 3.

(*5*) Corrected the metric conversion in S12.

(*6*) Added reference to Test Method F 1940 and Specification F 1941, and dropped reference to Specification B 633, in S13.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 193/A 193M – 06, that may impact the use of this specification. (Approved March 1, 2006).

(*1*) Revised Section 3 and inserted new Section 4.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 193/A 193M – 05, that may impact the use of this specification. (Approved January 15, 2006).

(*1*) Revised title and scope to agree with that of Specification A 194/A 194M.

SKE 280608

Designation: A 193/A 193M – 08

Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications[1]

This standard is issued under the fixed designation A 193/A 193M; 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*

1.1 This specification[2] covers alloy and stainless steel bolting material for pressure vessels, valves, flanges, and fittings for high temperature or high pressure service, or other special purpose applications. The term *bolting material* as used in this specification covers bars, bolts, screws, studs, stud bolts, and wire. Bars and wire shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be carbide solution treated or carbide solution treated and strain-hardened. When strain hardened austenitic steel is ordered, the purchaser should take special care to ensure that Appendix X1 is thoroughly understood.

1.2 Several grades are covered, including ferritic steels and austenitic stainless steels designated B5, B8, and so forth. Selection will depend upon design, service conditions, mechanical properties, and high temperature characteristics.

NOTE 1—The committee formulating this specification has included fifteen steel types that have been rather extensively used for the present purpose. Other compositions will be considered for inclusion by the committee from time to time as the need becomes apparent.

NOTE 2—For grades of alloy-steel bolting material suitable for use at the lower range of high temperature applications, reference should be made to Specification A 354.

NOTE 3—For grades of alloy-steel bolting material suitable for use in low temperature applications, reference should be made to Specification A 320/A 320M.

1.3 Nuts for use with this bolting material are covered in Section 14.

1.4 Supplementary Requirements S1 through S10 are provided for use when additional tests or inspection are desired. These shall apply only when specified in the purchase order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable *M* specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. 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. Within the text, the SI units are shown in brackets.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
A 320/A 320M Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service
A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
A 788/A 788M Specification for Steel Forgings, General Requirements
A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
B 696 Specification for Coatings of Cadmium Mechanically Deposited
B 766 Specification for Electrodeposited Coatings of Cadmium

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-193 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.

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

E 18 Test Methods for Rockwell Hardness of Metallic Materials
E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials
E 112 Test Methods for Determining Average Grain Size
E 139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
E 150 Recommended Practice for Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of Rapid Heating and Short Times[4]
E 151 Recommended Practice for Tension Tests of Metallic Materials at Elevated Temperatures With Rapid Heating and Conventional or Rapid Strain Rates[4]
E 292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials
E 328 Test Methods for Stress Relaxation for Materials and Structures
E 566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals
E 709 Guide for Magnetic Particle Testing
E 606 Practice for Strain-Controlled Fatigue Testing
F 1940 Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners
F 1941 Specification for Electrodeposited Coatings on Threaded Fasteners (Unified Inch Screw Threads (UN/UNR))

2.2 *ANSI Standards:*[5]
B1.1 Screw Threads
B18.2.1 Square and Hex Bolts and Screws
B18.2.3.1M Metric Hex Cap Screws
B18.3 Hexagon Socket and Spline Socket Screws
B18.3.1M Metric Socket Head Cap Screws

2.3 *AIAG Standard:*[6]
AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

3. General Requirements and Ordering Information

3.1 The inquiry and orders shall include the following, as required, to describe the desired material adequately:

3.1.1 Heat-treated condition (that is, normalized and tempered, or quenched and tempered, for the ferritic materials, and carbide solution treated (Class 1), carbide solution treated after finishing (Class 1A), and carbide solution treated and strain-hardened (Classes 2, 2B and 2C), for the austenitic stainless steels; Classes 1B and 1C apply to the carbide solution-treated nitrogen-bearing stainless steels; Class 1D applies to material carbide solution treated by cooling rapidly from the rolling temperature),

3.1.2 Description of items required (that is, bars, bolts, screws, or studs),

3.1.3 Nuts, if required by purchaser, in accordance with 14.1,

3.1.4 Supplementary requirements, if any, and

3.1.5 Special requirements, in accordance with 7.3, 7.5.1, 11.2, 15.1, and 16.1.

3.2 *Coatings*—Coatings are prohibited unless specified by the purchaser (See Supplementary Requirements S13 and S14). When coated fasteners are ordered the purchaser should take special care to ensure that Appendix X2 is thoroughly understood.

4. Common Requirements

4.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between this specification and Specification A 962/A 962M, this specification shall prevail.

5. Manufacture (Process)

5.1 The steel shall be produced by any of the following processes: open-hearth, basic-oxygen, electric-furnace, or vacuum-induction melting (VIM). The molten steel may be vacuum-treated prior to or during pouring of the ingot or strand casting.

5.2 *Quality*—See Specification A 962/A 962M for requirements.

6. Discard

6.1 A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

7. Heat Treatment

7.1 Ferritic steels shall be properly heat treated as best suits the high temperature characteristics of each grade. Immediately after rolling or forging, the bolting material shall be allowed to cool to a temperature below the cooling transformation range. The materials which are to be furnished in the liquid-quenched condition shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a *quenching charge*) and quenched in a liquid medium under substantially uniform conditions for each quenching charge. Use of water quenching is prohibited for any ferritic grade when heat treatment is part of the fastener manufacturing process. This prohibition does not apply to heat treated bar or to fasteners machined therefrom. The materials that are to be furnished in the normalized or air-quenched condition shall be reheated to the proper temperature to refine the grain and cooled uniformly in air to a temperature below the transformation temperature range. The material, whether liquid-quenched or normalized, shall then be uniformly reheated for tempering. The minimum tempering temperature shall be as specified in Table 2 and Table 3.

[4] Withdrawn.
[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[6] Available from Automotive Industry Action Group (AIAG), 26200 Lahser Rd., Suite 200, Southfield, MI 48033, http://www.aiag.org.

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TABLE 1 Chemical Requirements (Composition, percent)[A]

Type	Ferritic Steels			
Grade	B5		B6 and B6X	
Description.	5% Chromium		12 % Chromium	
UNS Designation			S41000 (410)	
	Range	Product Variation, Over or Under[B]	Range	Product Variation Over or Under[B]
Carbon	0.10 min	0.01 under	0.08–0.15	0.01 over
Manganese, max	1.00	0.03 over	1.00	0.03 over
Phosphorus, max	0.040	0.005 over	0.040	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00 max	0.05 over	1.00 max	0.05 over
Chromium	4.0–6.0	0.10	11.5–13.5	0.15
Molybdenum	0.40–0.65	0.05	. . .	. . .

Type	Ferritic Steels			
Grade	B7, B7M		B16	
Description	Chromium-Molybdenum[C]		Chromium-Molybdenum-Vanadium	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon	0.37–0.49[D]	0.02	0.36–0.47	0.02
Manganese	0.65–1.10	0.04	0.45–0.70	0.03
Phosphorus, max	0.035	0.005 over	0.035	0.005 over
Sulfur, max	0.040	0.005 over	0.040	0.005 over
Silicon	0.15–0.35	0.02	0.15–0.35	0.02
Chromium	0.75–1.20	0.05	0.80–1.15	0.05
Molybdenum	0.15–0.25	0.02	0.50–0.65	0.03
Vanadium	. . .	. . .	0.25–0.35	0.03
Aluminum, max %[E]	. . .	. . .	0.015	. . .

Type	Austenitic Steels,[F] Classes 1, 1A, 1D, and 2							
Grade . .	B8, B8A		B8C, B8CA		B8M, B8MA, B8M2, B8M3		B8P, B8PA	
UNS Designation	S30400 (304)		S34700 (347)		S31600 (316)		S30500	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.08	0.01 over	0.12	0.01 over
Manganese, max	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.030	0.005 over	0.030	0.005 over
Silicon, max	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over
Chromium	18.0–20.0	0.20	17.0–19.0	0.20	16.0–18.0	0.20	17.0–19.0	0.20
Nickel	8.0–11.0	0.15	9.0–12.0	0.15	10.0–14.0	0.15	11.0–13.0	0.15
Molybdenum	. . .	. . .	. . .	. . .	2.00–3.00	0.10	. . .	. . .
Columbium + tantalum	. . .	. . .	10 x carbon content, min; 1.10 max	0.05 under	. . .	. . .	. . .	. . .

Type	Austenitic Steels,[F] Classes 1A, 1B, 1D, and 2					
Grade	B8N, B8NA		B8MN, B8MNA		B8MLCuN, B8MLCuNA	
UNS Designation	S30451 (304N)		S31651 (316N)		S31254	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.020	0.005 over
Manganese, max	2.00	0.04 over	2.00	0.04 over	1.00	0.03 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.030	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.010	0.002 over
Silicon, max	1.00	0.05 over	1.00	0.05 over	0.80	0.05 over
Chromium	18.0–20.0	0.20	16.0–18.0	0.20	19.5–20.5	0.20
Nickel	8.0–11.0	0.15	10.0–13.0	0.15	17.5–18.5	0.15
Molybdenum	. . .	. . .	2.00–3.00	0.10	6.0–6.5	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01	0.18–0.22	0.02
Copper	. . .	. . .	. . .	. . .	0.50–1.00	. . .

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TABLE 1 *Continued*

Type	Austenitic Steels[F], Classes 1, 1A, and 2	
Grade	B8T, B8TA	
UNS Designation	S32100 (321)	
	Range	Product Variation, Over or Under[B]
Carbon, max	0.08	0.01 over
Manganese, max	2.00	0.04 over
Phosphorus, max	0.045	0.010 over
Sulfur, max	0.030	0.005 over
Silicon, max	1.00	0.05 over
Chromium	17.0–19.0	0.20
Nickel	9.0–12.0	0.15
Titanium	5 x (C + N) min, 0.70 max	0.05 under
Nitrogen	0.10 max	. . .

Type	Austenitic Steels[F], Classes 1C and 1D			
Grade	B8R, B8RA		B8S, B8SA	
UNS Designation	S20910		S21800	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.06	0.01 over	0.10	0.01 over
Manganese	4.0–6.0	0.05	7.0–9.0	0.06
Phosphorus, max	0.045	0.005 over	0.060	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00 max	0.05 over	3.5–4.5	0.15
Chromium	20.5–23.5	0.25	16.0–18.0	0.20
Nickel	11.5–13.5	0.15	8.0–9.0	0.10
Molybdenum	1.50–3.00	0.10	. . .	. . .
Nitrogen	0.20–0.40	0.02	0.08–0.18	0.01
Columbium + tantalum	0.10–0.30	0.05	. . .	. . .
Vanadium	0.10–0.30	0.02	. . .	. . .

Type	Austenitic Steels[F], Classes 1, 1A and 1D			
Grade	B8LN, B8LNA		B8MLN, B8MLNA	
UNS Designation	S30453		S31653	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.030	0.005 over	0.030	0.005 over
Manganese	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00	0.05 over	1.00	0.05 over
Chromium	18.0–20.0	0.20	16.0–18.0	0.20
Nickel	8.0–11.0	0.15	10.0–13.0	0.15
Molybdenum	. . .	. . .	2.00–3.00	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01

[A] The intentional addition of Bi, Se, Te, and Pb is not permitted.
[B] Product analysis—Individual determinations sometimes vary from the specified limits on ranges as shown in the tables. The several determinations of any individual element in a heat may not vary both above and below the specified range.
[C] Typical steel compositions used for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H.
[D] For bar sizes over 3½ in. [90 mm], inclusive, the carbon content may be 0.50 %, max. For the B7M grade, a minimum carbon content of 0.28 % is permitted, provided that the required tensile properties are met in the section sizes involved; the use of AISI 4130 or 4130H is allowed.
[E] Total of soluble and insoluble.
[F] Classes 1 and 1D are solution treated. Classes 1, 1B, and some 1C (B8R and B8S) products are made from solution treated material. Class 1A (B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, and B8MNA) and some Class 1C (B9RA and B8SA) products are solution treated in the finished condition. Class 2 products are solution treated and strain hardened.

TABLE 2 Mechanical Requirements — Inch Products

Grade	Diameter, in.	Minimum Tempering Temperature, °F	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
Ferritic Steels							
B5 4 to 6 % chromium	up to 4, incl	1100	100	80	16	50	. . .
B6 13 % chromium	up to 4, incl	1100	110	85	15	50	. . .
B6X 13 % chromium	up to 4, incl	1100	90	70	16	50	26 HRC
B7 Chromium-molybdenum	2½ and under	1100	125	105	16	50	321 HB or 35 HRC
	over 2½ to 4	1100	115	95	16	50	321 HB or 35 HRC
	over 4 to 7	1100	100	75	18	50	321 HB or 35 HRC
B7M[A] Chromium-molybdenum	4 and under	1150	100	80	18	50	235 HB or 99 HRB
	over 4 to 7	1150	100	75	18	50	235 BHN or 99 HRB
B16 Chromium-molybdenum-vanadium	2½ and under	1200	125	105	18	50	321 HB or 35 HRC
	over 2½ to 4	1200	110	95	17	45	321 HB or 35 HRC
	over 4 to 8	1200	100	85	16	45	321 HB or 35 HRC

Grade, Diameter, in.	Heat Treatment[B]	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
Austenitic Steels						
Classes 1 and 1D; B8, B8M, B8P, B8LN, B8MLN, all diameters	carbide solution treated	75	30	30	50	223 HB[C] or 96 HRB
Class 1: B8C, B8T, all diameters	carbide solution treated	75	30	30	50	223 HB[C] or 96HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA B8MLCuNA, all diameters	carbide solution treated in the finished condition	75	30	30	50	192 HB or 90 HRB
Classes 1B and 1D: B8N, B8MN, and B8MLCuN, all diameters	carbide solution treated	80	35	30	40	223 HB[C] or 96 HRB
Classes 1C and 1D: B8R, all diameters	carbide solution treated	100	55	35	55	271 HB or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	100	55	35	55	271 HB or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated	95	50	35	55	271 HB or 28 HRC
Classes 1C: B8SA, all diameters	carbide solution treated in the finished condition	95	50	35	55	271 HB or 28 HRC
Class 2: B8, B8C, B8P, B8T, and B8N,[D] ¾ and under	carbide solution treated and strain hardened	125	100	12	35	321 HB or 35 HRC
over ¾ to 1, incl		115	80	15	35	321 HB or 35 HRC
over 1 to 1¼, incl		105	65	20	35	321 HB or 35 HRC
over 1¼ to 1½, incl		100	50	28	45	321 HB or 35 HRC
Class 2: B8M, B8MN, B8MLCuN[D] ¾ and under	carbide solution treated and strain hardened	110	95	15	45	321 HB or 35 HRC
over ¾ to 1 incl		100	80	20	45	321 HB or 35 HRC
Over 1 to 1¼, incl		95	65	25	45	321 HB or 35 HRC
over 1¼ to 1½, incl		90	50	30	45	321 HB or 35 HRC
Class 2B: B8, B8M2[D] 2 and under	carbide solution treated and strain hardened	95	75	25	40	321 HB or 35 HRC

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TABLE 2 *Continued*

Grade, Diameter, in.	Heat Treatment[B]	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
		Austenitic Steels				
over 2 to 2½ incl		90	65	30	40	321 HB or 35 HRC
over 2½ to 3 incl		80	55	30	40	321 HB or 35 HRC
Class 2C: B8M3[D] 2 and under	carbide solution treated and strain hardened	85	65	30	60	321 HB or 35 HRC
over 2		85	60	30	60	321 HB or 35 HRC

[A] To meet the tensile requirements, the Brinell hardness shall be over 200 HB (93 HRB).

[B] Class 1 is solution treated. Class 1A is solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement. Class 2 is solution treated and strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over ¾ in. in diameter.

[C] For sizes ¾ in. in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.

[D] For diameters 1½ and over, center (core) properties may be lower than indicated by test reports which are based on values determined at ½ radius.

TABLE 3 **Mechanical Requirements —Metric Products**

Class	Diameter, [mm]	Minimum Tempering Temperature, °C	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
		Ferritic Steels					
B5 4 to 6 % chromium	up to M100, incl	593	690	550	16	50	. . .
B6 13 % chromium	up to M100, incl	593	760	585	15	50	. . .
B6X 13 % chromium	up to M100, incl	593	620	485	16	50	26 HRC
B7 Chromium-molybdenum	M64 and under	593	860	720	16	50	321 HB or 35 HRC
	over M64 to M100	593	795	655	16	50	321 HB or 35 HRC
	over M100 to M180	593	690	515	18	50	321 HB or 35 HRC
B7M[A] Chromium-molybdenum	M100 and under	620	690	550	18	50	235 HB or 99 HRB
	over M100 to M180	620	690	515	18	50	235 BHN or 99 HRB
B16 Chromium-molybdenum-vanadium	M64 and under	650	860	725	18	50	321 HB or 35 HRC
	over M64 to M100	650	760	655	17	45	321 HB or 35 HRC
	over M100 to M180	650	690	585	16	45	321 HB or 35 HRC

Class Diameter, mm	Heat Treatment[B]	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
		Austenitic Steels				
Classes 1 and 1D; B8, B8M, B8P, B8LN, B8MLN, all diameters	carbide solution treated	515	205	30	50	223 HB[C] or 96 HRB
Class 1: B8C, B8T, all diameters	carbide solution treated	515	205	30	50	223 HB[C] or 96HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA B8MLCuNA, all diameters	carbide solution treated in the finished condition	515	205	30	50	192 HB or 90 HRB
Classes 1B and 1D: B8N, B8MN, and B8MLCuN, all diameters	carbide solution treated	550	240	30	40	223 HB[C] or 96 HRB
Classes 1C and 1D: B8R, all diameters	carbide solution treated	690	380	35	55	271 HB or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	690	380	35	55	271 HB or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated	655	345	35	55	271 HB or 28 HRC

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TABLE 3 *Continued*

Class Diameter, mm	Heat Treatment[B]	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
		Austenitic Steels				
Classes 1C: B8SA, all diameters	carbide solution treated in the finished condition	655	345	35	55	271 HB or 28 HRC
Class 2: B8, B8C, B8P, B8T, and B8N,[D] M20 and under	carbide solution treated and strain hardened	860	690	12	35	321 HB or 35 HRC
over M20 to M24, incl		795	550	15	35	321 HB or 35 HRC
over M24 to M30, incl		725	450	20	35	321 HB or 35 HRC
over M30 to M36, incl		690	345	28	45	321 HB or 35 HRC
Class 2: B8M, B8MN, B8MLCuN,[D] M20 and under	carbide solution treated and strain hardened	760	655	15	45	321 HB or 35 HRC
over M20 to M24, incl		690	550	20	45	321 HB or 35 HRC
over M24 to M30, incl		655	450	25	45	321 HB or 35 HRC
over M30 to M36, incl		620	345	30	45	321 HB or 35 HRC
Class 2B: B8, B8M2,[D] M48 and under	carbide solution treated and strain hardened	655	515	25	40	321 HB or 35 HRC
over M48 to M64, incl		620	450	30	40	321 HB or 35 HRC
over M64 to M72, incl		550	380	30	40	321 HB or 35 HRC
Class 2C: B8M3,[D] M48 and under	carbide solution treated and strain hardened	585	450	30	60	321 HB or 35 HRC
over M48		585	415	30	60	321 HB or 35 HRC

[A] To meet the tensile requirements, the Brinell hardness shall be over 200 HB (93 HRB).
[B] Class 1 is solution treated. Class 1A is solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement. Class 2 is solution treated and strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over M20 mm in diameter
[C] For sizes M20 mm in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.
[D] For diameters M38 and over, center (core) properties may be lower than indicated by test reports which are based on values determined at ½ radius.

7.1.1 Quenched and tempered or normalized and tempered ferritic material that is subsequently cold drawn for dimensional control shall be stress-relieved after cold drawing. The minimum stress-relief temperature shall be 100 °F [55 °C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

7.2 Both B6 and B6X materials shall be held, at the tempering temperature for a minimum time of 1 h. Identification Symbol B 6X material may be furnished in the as-rolled-and-tempered condition. Cold working is permitted with the hardness limitation (26 HRC maximum) of Table 2 for the B 6X grade.

7.3 All austenitic stainless steels shall receive a carbide solution treatment (see 7.3.1-7.3.4 for specific requirements for each class). Classes 1, 1B, 1C (Grades B8R and B8S only), 2, 2B, and 2C can apply to bar, wire, and finished fasteners. Class 1A (all grades) and Class 1C (grades B8RA and B8SA only) can apply to finished fasteners. Class 1D applies only to bar and wire and finished fasteners that are machined directly from Class 1D bar or wire without any subsequent hot or cold working.

7.3.1 *Classes 1 and 1B, and Class 1C Grades B8R and B8S*—After rolling of the bar, forging, or heading, whether done hot or cold, the material shall be heated from ambient temperature and held a sufficient time at a temperature at which the chromium carbide will go into solution and then shall be cooled at a rate sufficient to prevent the precipitation of the carbide.

7.3.2 *Class 1D*—Rolled or forged Grades B8, B8M, B8P, B8LN, B8MLN, B8N, B8MN, B8R, and B8S bar shall be cooled rapidly immediately following hot working while the temperature is above 1750 °F [955 °C] so that grain boundary carbides are in solution. Class 1D shall be restricted to applications at temperatures less than 850 °F [455 °C].

7.3.3 *Class 1A and Class 1C Grades B8RA and B8SA*—Finished fasteners shall be carbide solution treated after all rolling, forging, heading, and threading operations are complete. This designation does not apply to starting material such as bar. Fasteners shall be heated from ambient temperature and held a sufficient time at a temperature at which the chromium carbide will go into solution and then shall be cooled at a rate sufficient to prevent the precipitation of the carbide.

7.3.4 *Classes 2, 2B, and 2C*—Material shall be carbide solution treated by heating from ambient temperature and holding a sufficient time at a temperature at which the chromium carbide will go into solution and then cooling at a rate sufficient to prevent the precipitation of the carbide. Following this treatment the material shall then be strain hardened to achieve the required properties.

NOTE 4—Heat treatment following operations performed on a limited portion of the product, such as heading, may result in non-uniform grain size and mechanical properties through the section affected.

7.4 If scale-free bright finish is required, this shall be specified in the purchase order.

7.5 B7 and B7M bolting material shall be heat treated by quenching in a liquid medium and tempering. For B7M bolting, the final heat treatment, which may be the tempering operation if conducted at 1150 °F [620 °C] minimum, shall be done after all machining and forming operations, including thread rolling and any type of cutting. Surface preparation for

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hardness testing, nondestructive evaluation, or ultrasonic bolt tensioning is permitted.

7.5.1 Unless otherwise specified, material for Grade B7 may be heat treated by the Furnace, the Induction or the Electrical Resistance method.

NOTE 5—It should be taken into consideration that stress-relaxation properties may vary from heat lot to heat lot or these properties may vary from one heat treating method to another. The purchaser may specify Supplementary Requirement S8, if stress-relaxation testing is desired.

7.6 Material Grade B16 shall be heated to a temperature range from 1700 to 1750 °F [925 to 955 °C] and oil quenched. The minimum tempering temperature shall be as specified in Table 2.

8. Chemical Composition

8.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 1.

8.2 The steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element. Furthermore, elements present in concentrations greater than 0.75 weight/% shall be reported.

9. Heat Analysis

9.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 8. The chemical composition thus determined shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 8. Should the purchaser deem it necessary to have the transition zone of two heats sequentially cast discarded, the purchaser shall invoke Supplementary Requirement S3 of Specification A 788.

10. Mechanical Properties

10.1 *Tensile Properties*:

10.1.1 *Requirements*—The material as represented by the tension specimens shall conform to the requirements prescribed in Table 2 at room temperature after heat treatment. Alternatively, stainless strain hardened headed fasteners (Class 2, 2B, and 2C) shall be tested full size after strain hardening to determine tensile strength and yield strength and shall conform to the requirements prescribed in Table 2. Should the results of full size tests conflict with results of tension specimen tests, full size test results shall prevail.

10.1.2 *Full Size Fasteners, Wedge Tensile Testing*—When applicable, see 13.1.3, headed fasteners shall be wedge tested full size and shall conform to the tensile strength shown in Table 2. The minimum full size breaking strength (lbf) for individual sizes shall be as follows:

$$Ts = UTS \times As \quad (1)$$

where:

Ts = wedge tensile strength,
UTS = tensile strength specified in Table 2, and
As = stress area, square inches, as shown in ANSI B1.1 or calculated as follows:

$$As = 0.785\,(D - (0.974/n))^2 \quad (2)$$

where:

D = nominal thread size, and
n = the number of threads per inch.

10.2 *Hardness Requirements*:

10.2.1 The hardness shall conform to the requirements prescribed in Table 2. Hardness testing shall be performed in accordance with either Specification A 962/A 962M or with Test Methods F 606.

10.2.2 *Grade B7M*—The maximum hardness of the grade shall be 235 HB or 99 HRB. The minimum hardness shall not be less than 200 HB or 93 HRB. Conformance to this hardness shall be ensured by testing the hardness of each stud or bolt by Brinell or Rockwell B methods in accordance with 10.2.1. The use of 100 % electromagnetic testing for hardness as an alternative to 100 % indentation hardness testing is permissible when qualified by sampling using indentation hardness testing. Each lot tested for hardness electromagnetically shall be 100 % examined in accordance with Practice E 566. Following electromagnetic testing for hardness a random sample of a minimum of 100 pieces of each heat of steel in each lot (as defined in 13.1.1) shall be tested by indentation hardness methods. All samples must meet hardness requirements to permit acceptance of the lot. If any one sample is outside of the specified maximum or minimum hardness, the lot shall be rejected and either reprocessed and resampled or tested 100 % by indentation hardness methods. Product that has been 100 % tested and found acceptable shall have a line under the grade symbol.

10.2.2.1 Surface preparation for indentation hardness testing shall be in accordance with Test Methods E 18. Hardness tests shall be performed on the end of the bolt or stud. When this is impractical, the hardness test shall be performed elsewhere.

11. Workmanship, Finish, and Appearance

11.1 Bolts, screws, studs, and stud bolts shall be pointed and shall have a workmanlike finish. Points shall be flat and chamfered or rounded at option of the manufacturer. Length of point on studs and stud bolts shall be not less than one nor more than two complete threads as measured from the extreme end parallel to the axis. Length of studs and stud bolts shall be measured from first thread to first thread.

11.2 Bolt heads shall be in accordance with the dimensions of ANSI B18.2.1 or ANSI B18.2.3.1M. Unless otherwise specified in the purchase order, the Heavy Hex Screws Series should be used, except the maximum body diameter and radius of fillet may be the same as for the Heavy Hex Bolt Series. The body diameter and head fillet radius for sizes of Heavy Hex Cap Screws and Bolts that are not shown in their respective tables in ANSI B18.2.1 or ANSI B18.2.3.1M may be that shown in the corresponding Hex Cap Screw and Bolt Tables respectively. Socket head fasteners shall be in accordance with ANSI B18.3 or ANSI B18.3.1M.

12. Retests

12.1 If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two

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additional tension tests shall be made from such lot, all of which shall conform to the requirements specified.

13. Test Specimens

13.1 *Number of Tests*—For heat-treated bars, one tension test shall be made for each diameter of each heat represented in each tempering charge. When heat treated without interruption in continuous furnaces, the material in a lot shall be the same heat, same prior condition, same size, and subjected to the same heat treatment. Not fewer than two tension tests are required for each lot containing 20 000 lb [9000 kg] or less. Every additional 10 000 lb [4500 kg] or fraction thereof requires one additional test.

13.1.1 For studs, bolts, screws, and so forth, one tension test shall be made for each diameter of each heat involved in the lot. Each lot shall consist of the following:

Diameter, in. [mm]	Lot Size
1⅛ [30] and under	1500 lb [780 kg] or fraction thereof
Over 1⅛ [30] to 1¾ [42], incl	4500 lb [2000 kg] or fraction thereof
Over 1¾ [42] to 2½ [64], incl	6000 lb [2700 kg] or fraction thereof
Over 2½ [64]	100 pieces or fraction thereof

13.1.2 Tension tests are not required to be made on bolts, screws, studs, or stud bolts that are fabricated from heat-treated bars furnished in accordance with the requirements of this specification and tested in accordance with 13.1, provided they are not given a subsequent heat treatment.

13.1.3 *Full Size Specimens, Headed Fasteners*—Headed fasteners 1½ in. in body diameter and smaller, with body length three times the diameter or longer, and that are produced by upsetting or forging (hot or cold) shall be subjected to full size testing in accordance with 10.1.2. This testing shall be in addition to tensile testing as specified in 10.1.1. The lot size shall be as shown in 13.1.1. Failure shall occur in the body or threaded section with no failure, or indications of failure, such as cracks, at the junction of the head and shank.

14. Nuts

14.1 Bolts, studs, and stud bolts shall be furnished with nuts, when specified in the purchase order. Nuts shall conform to Specification A 194/A 194M.

15. Rejection and Rehearing

15.1 Unless otherwise specified in the basis of purchase, any rejection based on product analysis shall be reported to the manufacturer within 30 days from the receipt of samples by the purchaser.

15.2 Material that shows defects subsequent to its acceptance at the place of manufacture shall be rejected, and the manufacturer shall be notified.

15.3 *Product Analysis*—Samples that represent rejected material shall be preserved for two weeks from the date of the test report. In the case of dissatisfaction with the results of the test, the manufacturer may make claim for a rehearing within that time.

16. Certification

16.1 The producer of the raw material or finished fasteners shall furnish a certification to the purchaser or his representative showing the results of the chemical analysis, macroetch examination (Carbon and Alloy Steels Only), and mechanical tests, and state the method of heat treatment employed.

16.2 Certification shall also include at least the following:

16.2.1 A statement that the material or the fasteners, or both, were manufactured, sampled, tested, and inspected in accordance with the specification and any supplementary requirements or other requirements designated in the purchase order or contract and was found to meet those requirements.

16.2.2 The specification number, year date, and identification symbol.

17. Product Marking

17.1 The marking symbol and manufacturer's identification symbol shall be applied to one end of studs ⅜ in. [10 mm] in diameter and larger and to the heads of bolts ¼ in. [6 mm] in diameter and larger. (If the available area is inadequate, the marking symbol may be placed on one end with the manufacturer's identification symbol placed on the other end.) The marking symbol shall be as shown in Table 4 and Table 5. Grade B7M, which has been 100 % evaluated in conformance with the specification, shall have a line under the marking symbol to distinguish it from B7M produced to previous specification revisions not requiring 100 % hardness testing.

17.2 For bolting materials, including threaded bars, furnished bundled and tagged or boxed, the tags and boxes shall carry the marking symbol for the material identification and the manufacturer's identification symbol or name.

17.3 For purposes of product marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

17.4 *Bar Coding*—In addition to the requirements in 17.1, 17.2, and 17.3, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG Standard B-5 02.00. If used on small items, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 hardness; heat treatment

TABLE 4 Marking of Ferritic Steels

Grade	Marking Symbol
B5	B5
B6	B6
B6X	B6X
B7	B7
B7M[A]	B7M
	<u>B7M</u>
B16	B16
B16 + Supplement S12	B16R

[A] For explanations, see 10.2.2 and 17.1.

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TABLE 5 Marking of Austenitic Steels

Class	Grade	Marking Symbol
Class 1	B8	B8
	B8C	B8C
	B8M	B8M
	B8P	B8P
	B8T	B8T
	B8LN	B8F or B8LN
	B8MLN	B8G or B8MLN
Class 1A	B8A	B8A
	B8CA	B8B or B8CA
	B8MA	B8D or B8MA
	B8PA	B8H or B8PA
	B8TA	B8J or B8TA
	B8LNA	B8L or B8LNA
	B8MLNA	B8K or B8MLNA
	B8NA	B8V or B8MA
	B8MNA	B8W or B8MNA
	B8MLCuNA	B9K or B8MLCuNA
Class 1B	B8N	B8N
	B8MN	B8Y or B8MN
	B8MLCuN	B9J or B8MLCuN
Class 1C	B8R	B9A or B8R
	B8RA	B9B or B8RA
	B8S	B9D or B8S
	B8SA	B9F or B8SA
Class 1D	B8	B94
	B8M	B95
	B8P	B96
	B8LN	B97
	B8MLN	B98
	B8N	B99
	B8MN	B100
	B8R	B101
	B8S	B102
Class 2	B8	B8SH
	B8C	B8CSH
	B8P	B8PSH
	B8T	B8TSH
	B8N	B8NSH
	B8M	B8MSH
	B8MN	B8YSH
	B8MLCuN	B0JSH
Class 2B	B8M2	B9G or B8M2
	B8	B9
Class 2C	B8M3	B9H or B8M3

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order and in the Ordering Information, in which event the specified tests shall be made before shipment of the product.

S1. High Temperature Tests

S1.1 Tests to determine high temperature properties shall be made in accordance with Test Methods E 21, E 139, and E 292, and Practices E 150 and E 151.

S2. Charpy Impact Tests

S2.1 Charpy impact tests based on the requirements of Specification A 320/A 320M, Sections 6 and 7, shall be made as agreed between the manufacturer and the purchaser. When testing temperatures are as low as those specified in Specification A 320/A 320M, bolting should be ordered to that specification in preference to this specification.

S3. 100 % Hardness Testing of Grade B7M

S3.1 Each Grade B7M bolt or stud shall be tested for hardness by indentation method and shall meet the requirements specified in Table 2.

S4. Hardness Testing of Grade B16

S4.1 For bolts or studs 2½ in. [65 mm] or smaller, the hardness for Grade B16 shall be measured on or near the end of each bolt or stud using one of the methods prescribed in 10.2.1 for the Brinell or Rockwell C test. The hardness shall be in the range 253–319 HB or 25–34 HRC.

S5. Product Marking

S5.1 Marking and manufacturer's identification symbols shall be applied to one end of studs and to the heads of bolts of all sizes. (If the available area is inadequate, the marking symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) For bolts smaller than ¼ in. [6 mm] in diameter and studs smaller than ⅜ in. [10 mm] in diameter and for ¼ in. [6 mm] in diameter studs requiring more than a total of three symbols, the marking shall be a matter of agreement between the purchaser and the manufacturer.

S6. Stress Relieving

S6.1 A stress-relieving operation shall follow straightening after heat treatment.

S6.2 The minimum stress-relieving temperature shall be 100 °F [55 °C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

S7. Magnetic Particle Inspection

S7.1 Bars shall be magnetic particle examined in accordance with Guide E 709. Bars with indications of cracks or seams are subject to rejection if the indications extend more than 3 % of the diameter into the bar.

S8. Stress-Relaxation Testing

S8.1 Stress-Relaxation Testing, when required, shall be done in accordance with Test Methods E 328. The test shall be performed at 850 °F [454 °C] for a period of 100 h. The initial stress shall be 50 M psi [345 MPa]. The residual stress at 100 h shall be 17 M psi [117 MPa] minimum.

S9. Grain Size Requirements for Non H Grade Austenitic Steels Used Above 1000 °F

S9.1 For design metal temperatures above 1000 °F [540 °C], the material shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E 112. The grain size so determined shall be reported on the Certificate of Test.

S10. Hardness Testing of Class 2 Bolting Materials for ASME Applications

S10.1 The maximum hardness shall be Rockwell C35 immediately under the thread roots. The hardness shall be taken on a flat area at least ⅛ in. [3 mm] across, prepared by removing threads, and no more material than necessary shall be removed to prepare the flat areas. Hardness determinations shall be made at the same frequency as tensile tests.

S11. Thread Forming

S11.1 Threads shall be formed after heat treatment. Application of this supplemental requirement to grade B7M or the grades listed in 7.3.3 is prohibited.

S12. Stress Rupture Testing of Grade B16

S12.1 One test shall be made for each heat treat lot. Testing shall be conducted using a combination test bar in accordance with Test Methods E 292. Rupture shall occur in the smooth section of each test specimen. The test shall be conducted at 1100 °F [595 °C] and 20 ksi [140 MPa]. The test shall be continued until the sample ruptures. Rupture life shall be 25 h minimum. Testing is not required on material less than ½ in. [12 mm] thick.

S12.2 When a purchase order for fasteners invokes S12, the product marking supplied shall be "B16R."

S13. Coatings on Bolting Materials

S13.1 It is the purchaser's responsibility to specify in the purchase order all information required by the coating facility. Examples of such information may include but are not limited to the following:

S13.1.1 Reference to the appropriate coating specification and type, thickness, location, modification to dimensions, and hydrogen embrittlement relief.

S13.1.2 Reference to Specifications A 153/A 153M, B 695, B 696, B 766, or F 1941, Test Method F 1940, or other standards.

S14. Marking Coated Bolting Materials

S14.1 Material coated with zinc shall have an asterisk (*) marked after the grade symbol. Material coated with cadmium shall have a plus sign (+) marked after the grade symbol.

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APPENDIXES

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars or wire to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle, and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening.

X1.2 Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined. The minimum bar size that can be used, however, is established by the configuration of the fastener so that the configuration can affect the strength of the fastener.

X1.3 For example, a stud of a particular alloy and size may be machined from a smaller diameter bar than a bolt of the same alloy and size because a larger diameter bar is required to accommodate the head of the bolt. The stud, therefore, is likely to be stronger than the same size bolt in a given alloy.

X2. COATINGS AND APPLICATION LIMITS

X2.1 Use of coated fasteners at temperatures above approximately one-half the melting point (Fahrenheit or Celsius) of the coating is not recommended unless consideration is given to the potential for liquid and solid metal embrittlement, or both. The melting point of elemental zinc is approximately 780 °F [415 °C]. Therefore, application of zinc-coated fasteners should be limited to temperatures less than 390 °F [210 °C]. The melting point of cadmium is approximately 600 °F [320 °C]. Therefore, application of cadmium-coated fasteners should be limited to temperatures less than 300 °F [160 °C].

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 193/A 193M – 07, that may impact the use of this specification. (Approved April 1, 2008).

(*1*) Added new Supplementary Requirement S14.

(*2*) Added Nitrogen for Grades B8T and B8TA in Table 1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 193/A 193M – 06a, that may impact the use of this specification. (Approved March 1, 2007).

(*1*) Deleted the space between the S and the numbers in the UNS designations in Table 1.

(*2*) Added permissible product variations for B8MLCuN and B8MLCuNA in Table 1.

(*3*) Added the requirement to report nitrogen for S32100 and changed the order of the elements in Table 1 for this grade to be consistent with the other stainless grades.

(*4*) Corrected the metric yield strength for B16 M100 to M180 in Table 3.

(*5*) Corrected the metric conversion in S12.

(*6*) Added reference to Test Method F 1940 and Specification F 1941, and dropped reference to Specification B 633, in S13.

FOR INTERNAL REFERENCE ONLY

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Designation: A 192/A 192M – 02

Standard Specification for Seamless Carbon Steel Boiler Tubes for High-Pressure Service[1]

This standard is issued under the fixed designation A 192/A 192M; 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 *

1.1 This specification[2] covers minimum-wall-thickness, seamless carbon steel boiler and superheater tubes for high-pressure service.

1.2 The tubing sizes and thicknesses usually furnished to this specification are ½ in. to 7 in. [12.7 to 177.8 mm] outside diameter and 0.085 to 1.000 in. [2.2 to 25.4 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] inside diameter or 0.015 in. [0.4 mm] thickness.

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.

2. Referenced Documents

2.1 *ASTM Standards:*

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes[3]

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 tubes),

3.1.3 Manufacture (hot-finished or cold-finished),

3.1.4 Size (outside diameter and minimum wall thickness),

3.1.5 Length (specific or random),

3.1.6 Optional requirements (Section 8),

3.1.7 Test report required (see section on Certification of Specification A 450/A 450M),

3.1.8 Specification designation, and

3.1.9 Special requirements.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

5. Manufacture

5.1 Tubes shall be made by the seamless process and shall be either hot-finished or cold-finished, as specified.

6. Heat Treatment

6.1 Hot-finished tubes need not be heat treated. Cold-finished tubes shall be heat treated after the final cold-finishing at a temperature of 1200°F [650°C] or higher.

7. Chemical Composition

7.1 The steel shall conform to the following requirements as to chemical composition:

Carbon, %	0.06–0.18
Manganese, %	0.27–0.63
Phosphorus, max, %	0.035
Sulfur, max, %	0.035
Silicon, max, %	0.25

7.2 Supplying an alloy grade of steel that specifically requires the addition of any element other than those listed in 7.1 is not permitted.

8. Product Analysis

8.1 When requested on the purchase order, a product analysis shall be made by the supplier from one tube per 100 pieces for sizes over 3 in. [76.2 mm] and one tube per 250 pieces for

[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 A01.09 on Carbon Steel Tubular Products.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-192 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

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

sizes 3 in. [76.2 mm] and under; or when tubes are identified by heat, one tube per heat shall be analyzed. 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 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 (see Note 1) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 1—A lot consists of 250 tubes for sizes 3 in. [76.2 mm] and under and of 100 tubes for sizes over 3 in. [76.2 mm], prior to cutting to length.

9. Hardness Requirements

9.1 The tubes shall have a hardness number not exceeding the following:

Brinell Hardness Number (Tubes 0.200 in. [5.1 mm] and over in wall thickness)	Rockwell Hardness Number (Tubes less than 0.200 in. [5.1 mm] in wall thickness)
137 HB	77 HRB

10. Mechanical Tests Required

10.1 *Flattening Test*—One flattening test shall be made on specimens from each end of two tubes selected from each lot (see Note 1) or fraction thereof.

10.2 *Flaring Test*—One flaring test shall be made on specimens from each end of two tubes selected from each lot (see Note 1) or fraction thereof. These tubes shall be selected apart from those used for the flattening test.

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

10.4 *Hydrostatic Test*—Each tube shall be subjected to the hydrostatic pressure test, or instead of this test, a nondestructive test may be used when specified by the purchaser.

11. Forming Operations

11.1 Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects.

12. Product Marking

12.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall indicate whether the tube is hot finished or cold finished.

13. Keywords

13.1 boiler tubes; seamless steel tube; steel tube-carbon

EXPLANATORY NOTES

NOTE 1—For purposes of design, the following tensile properties may be assumed:

Tensile strength, min, ksi [MPa]	47 [325]
Yield strength, min, ksi [MPa]	26 [180]
Elongation in 2 in. or 50 mm, min, %	35

SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification that have been incorporated since the last edition, A 192/A 192M-91 (2001), as follows:

(1) Paragraph 1.4 was deleted and the subsequent subsection was renumbered.

(2) Paragraph 2.1 was revised to delete reference to Specification A 520.

Endorsed by Manufacturers Standardization
Society of the Valve and Fittings Industry
Used in USDOE-NE Standards

Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service[1]

This standard is issued under the fixed designation A 182/A 182M; 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*

1.1 This specification[2] covers forged low alloy and stainless steel piping components for use in pressure systems. Included are flanges, fittings, valves, and similar parts to specified dimensions or to dimensional standards, such as the ASME specifications that are referenced in Section 2.

1.2 For bars and products machined directly from bar, refer to Specifications A 479/A 479M and A 739 for the similar grades available in those specifications. Products made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. For larger products and products for other applications, refer to Specifications A 336/A 336M and A 965/A 965M for the similar ferritic and austenitic grades, respectively, available in those specifications.

1.3 Several grades of low alloy steels and ferritic, martensitic, austenitic, and ferritic-austenitic stainless steels are included in this specification. Selection will depend upon design and service requirements.

1.4 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as the 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.

2. Referenced Documents

2.1 In addition to the referenced documents listed in Specification A 961/A 961M, the following list of standards apply to this specification.

2.2 *ASTM Standards:* [3]

A 234/A 234M Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
A 262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
A 275/A 275M Practice for Magnetic Particle Examination of Steel Forgings
A 336/A 336M Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts
A 370 Test Methods and Definitions for Mechanical Testing of Steel Products
A 403/A 403M Specification for Wrought Austenitic Stainless Steel Piping Fittings
A 479/A 479M Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings
A 739 Specification for Steel Bars, Alloy, Hot-Wrought, for Elevated Temperature or Pressure-Containing Parts, or Both
A 763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels
A 788/A 788M Specification for Steel Forgings, General Requirements
A 961/A 961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications
A 965/A 965M Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts
E 112 Test Methods for Determining Average Grain Size

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-182 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.

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

E 165 Test Method for Liquid Penetrant Examination
E 340 Test Method for Macroetching Metals and Alloys

2.3 *ASME Boiler and Pressure Vessel Codes:*[4]

Section IX Welding Qualifications
SFA-5.4 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes
SFA-5.5 Specification for Low-Alloy Steel Covered Arc-Welding Electrodes
SFA-5.9 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes
SFA-5.11 Specification for Nickel and Nickel-Alloy Covered Welding Electrodes

3. Ordering Information

3.1 It is the purchaser's responsibility to specify in the purchase order information necessary to purchase the needed material. In addition to the ordering information guidelines in Specification A 961/A 961M, orders should include the following information:

3.1.1 Additional requirements (see 6.2.1, Table 2 footnotes, 8.3, and 17.2), and

3.1.2 Requirement, if any, that manufacturer shall submit drawings for approval showing the shape of the rough forging before machining and the exact location of test specimen material (see 8.3.1).

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 961/A 961M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 961/A 961M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 961/A 961M, this specification shall prevail.

5. Manufacture

5.1 The low-alloy ferritic steels shall be made by the open-hearth, electric-furnace, or basic-oxygen process with the option of separate degassing and refining processes in each case.

5.2 The stainless steels shall be melted by one of the following processes: *(a)* electric-furnace (with the option of separate degassing and refining processes); *(b)* vacuum-furnace; or *(c)* one of the former followed by vacuum or electroslag-consumable remelting. Grade F XM-27Cb may be produced by electron-beam melting.

5.3 A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

5.4 The material shall be forged as close as practicable to the specified shape and size. Except for flanges of any type, forged or rolled bar may be used without additional hot working for small cylindrically shaped parts within the limits defined by Specification A 234/A 234M for low alloy steels and martensitic stainless steels and Specification A 403/A 403M for austenitic and ferritic-austenitic stainless steels. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

5.5 Except as provided for in 5.4, the finished product shall be a forging as defined in the Terminology section of Specification A 788.

6. Heat Treatment[5]

6.1 After hot working, forgings shall be cooled to a temperature below 1000 °F [538 °C] prior to heat treating in accordance with the requirements of Table 1.

6.2 *Low Alloy Steels and Ferritic and Martensitic Stainless Steels*—The low alloy steels and ferritic and martensitic stainless steels shall be heat treated in accordance with the requirements of 6.1 and Table 1.

6.2.1 *Liquid Quenching*—When agreed to by the purchaser, liquid quenching followed by tempering shall be permitted provided the temperatures in Table 1 for each grade are utilized.

6.2.1.1 *Marking*—Parts that are liquid quenched and tempered shall be marked "QT."

6.2.2 Alternatively, Grade F 1, F 2, and F 12, Classes 1 and 2 may be given a heat treatment of 1200 °F [650 °C] minimum after final hot or cold forming.

6.3 *Austenitic and Ferritic-Austenitic Stainless Steels*—The austenitic and ferritic-austenitic stainless steels shall be heat treated in accordance with the requirements of 6.1 and Table 1.

6.3.1 Alternatively, immediately following hot working, while the temperature of the forging is not less than the minimum solution annealing temperature specified in Table 1, forgings made from austenitic grades (except grades F 304H, F 309H, F 310, F 310H, F 316H, F 321, F 321H, F 347, F 347H, F 348, F 348H, F 45, and F 56) may be individually rapidly quenched in accordance with the requirements of Table 1.

6.3.2 See Supplementary Requirement S8 if a particular heat treatment method is to be employed.

6.4 *Time of Heat Treatment*—Heat treatment of forgings may be performed before machining.

6.5 *Forged or Rolled Bar*—Forged or rolled austenitic stainless bar from which small cylindrically shaped parts are to be machined, as permitted by 5.4, and the parts machined from such bar, without heat treatment after machining, shall be furnished to the annealing requirements of Specification A 479/A 479M or this specification, with subsequent light cold drawing and straightening permitted (see Supplementary Requirement S3 if annealing must be the final operation).

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[5] A solution annealing temperature above 1950 °F [1065 °C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in F 321, F 321H, F 347, F 347H, F 348, and F 348H. When specified by the purchaser, a lower temperature stabilization or resolution annealing shall be used subsequent to the initial high temperature solution anneal (see Supplementary Requirement S10).

TABLE 1 Heat Treating Requirements

Grade	Heat Treat Type	Austenitizing/Solutioning Temperature, Minimum or Range, °F [°C][A]	Cooling Media	Quenching Cool Below °F [°C]	Tempering Temperature, Minimum or Range, °F [°C]
		Low Alloy Steels			
F 1	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1150 [620]
F 2	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1150 [620]
F 5, F 5a	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	[B]	1250 [675]
F 9	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	[B]	1250 [675]
F 10	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 91	normalize and temper	1900-1975 [1040-1080]	air cool	[B]	1350–1470 [730–800]
F 92	normalize and temper	1900-1975 [1040-1080]	air cool	[B]	1350–1470 [730–800]
F 122	normalize and temper	1900-1975 [1040-1080]	air cool	[B]	1350–1470 [730–800]
F 911	normalize and temper	1900-1975 [1040-1080]	air cool or liquid	[B]	1365–1435 [740-780]
F 11, Class 1, 2, 3	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1150 [620]
F 12, Class 1, 2	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1150 [620]
F 21, F 3V, and F 3VCb	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	[B]	1250 [675]
F 22, Class 1, 3	anneal	1650 [900]	furnace cool	[B]	[B]
	normalize and temper	1650 [900]	air cool	[B]	1250 [675]
F 22V	normalize and temper or quench and temper	1650 [900]	air cool or liquid	[B]	1250 [675]
F 23	normalize and temper	1900-1975 [1040-1080]	air cool accelerated cool	[B]	1350–1470 [730–800]
F 24	normalize and temper	1800-1975 [980-1080]	air cool or liquid	[B]	1350–1470 [730–800]
FR	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize	1750 [955]	air cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	[B]	1250 [675]
F 36, Class 1	normalize and temper	1650 [900]	air cool	[B]	1100 [595]
F 36, Class 2	normalize and temper	1650 [900]	air cool	[B]	1100 [595]
	quench and temper	1650 [900]	accelerated air cool or liquid		1100 [595]
		Martensitic Stainless Steels			
F 6a Class 1	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1325 [725]
	temper	not required	[B]	[B]	1325 [725]
F 6a Class 2	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1250 [675]
	temper	not required	[B]	[B]	1250 [675]
F 6a Class 3	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1100 [595]
F 6a Class 4	anneal	not specified	furnace cool	[B]	[B]
	normalize and temper	not specified	air cool	400 [205]	1000 [540]
F 6b	anneal	1750 [955]	furnace cool	[B]	[B]
	normalize and temper	1750 [955]	air cool	400 [205]	1150 [620]
F 6NM	normalize and temper	1850 [1010]	air cool	200 [95]	1040-1120 [560-600]
		Ferritic Stainless Steels			
F XM-27 Cb	anneal	1850 [1010]	furnace cool	[B]	[B]
F 429	anneal	1850 [1010]	furnace cool	[B]	[B]
F 430	anneal	not specified	furnace cool	[B]	[B]

TABLE 1 *Continued*

Grade	Heat Treat Type	Austenitizing/Solutioning Temperature, Minimum or Range, °F [°C][A]	Cooling Media	Quenching Cool Below °F [°C]	Tempering Temperature, Minimum or Range, °F [°C]
		Austenitic Stainless Steels			
F 304	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 304H	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 304L	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 304N	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 304LN	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 309H	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 310	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 310H	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 310MoLN	solution treat and quench	1900–2010 [1050–1100]	liquid	500 [260]	[B]
F 316	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 316H	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 316L	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 316N	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 316LN	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 316Ti	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 317	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 317L	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 347	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 347H	solution treat and quench	2000 [1095]	liquid	500 [260]	[B]
F 348	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 348H	solution treat and quench	2000 [1095]	liquid	500 [260]	[B]
F 321	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 321H	solution treat and quench	2000 [1095]	liquid	500 [260]	[B]
F XM-11	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F XM-19	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 20	solution treat and quench	1700-1850 [925-1010]	liquid	500 [260]	[B]
F 44	solution treat and quench	2100 [1150]	liquid	500 [260]	[B]
F 45	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 46	solution treat and quench	2010-2140 [1100-1140]	liquid	500 [260]	[B]
F 47	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 48	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 49	solution treat and quench	2050 [1120]	liquid	500 [260]	[B]
F 56	solution treat and quench	2050-2160 [1120-1180]	liquid	500 [260]	[B]
F 58	solution treat and quench	2085 [1140]	liquid	500 [260]	[B]
F 62	solution treat and quench	2025 [1105]	liquid	500 [260]	[B]
F 63	solution treat and quench	1900 [1040]	liquid	500 [260]	[B]
F 64	solution treat and quench	2010-2140 [1100-1170]	liquid	500 [250]	[B]
F 904L	solution treat and quench	1920-2100 [1050-1150]	liquid	500 [260]	[B]
		Ferritic-Austenitic Stainless Steels			
F 50	solution treat and quench	1925 [1050]	liquid	500 [260]	[B]
F 51	solution treat and quench	1870 [1020]	liquid	500 [260]	[B]
F 52[C]			liquid	500 [260]	[B]
F 53	solution treat and quench	1880 [1025]	liquid	500 [260]	[B]
F 54	solution treat and quench	1920-2060 [1050-1125]	liquid	500 [260]	[B]
F 55	solution treat and quench	2010-2085 [1100-1140]	liquid	500 [260]	[B]
F 57	solution treat and quench	1940 [1060]	liquid	175 [80]	[B]
F 59	solution treat and quench	1975-2050 [1080-1120]	liquid	500 [260]	[B]
F 60	solution treat and quench	1870 [1020]	liquid	500 [260]	[B]
F 61	solution treat and quench	1920-2060 [1050-1125]	liquid	500 [260]	[B]
F 65	solution treat and quench	1905-2100 [1040-1150]	liquid	500 [260]	[B]

[A] Minimum unless temperature range is listed.
[B] Not applicable.
[C] Grade F 52 shall be solution treated at 1825 to 1875 °F [995 to 1025 °C] 30 min/in. of thickness and water quenched.

7. Chemical Composition

7.1 A chemical heat analysis in accordance with Specification A 961/A 961M shall be made and conform to the chemical composition prescribed in Table 2.

7.2 Grades to which lead, selenium, or other elements are added for the purpose of rendering the material free-machining shall not be used.

7.3 Starting material produced to a specification that specifically requires the addition of any element beyond those listed in Table 2 for the applicable grade of material is not permitted.

7.4 Steel grades covered in this specification shall not contain an unspecified element, other than nitrogen in stainless steels, for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation or Grade designation and identification symbol in Table 2.

7.5 *Product Analysis*—The purchaser may make a product analysis on products supplied to this specification in accordance with Specification A 961/A 961M.

8. Mechanical Properties

8.1 The material shall conform to the requirements as to mechanical properties for the grade ordered as listed in Table 3.

8.2 Mechanical test specimens shall be obtained from production forgings, or from separately forged test blanks prepared from the stock used to make the finished product. In either case, mechanical test specimens shall not be removed until after all heat treatment is complete. If repair welding is required, test specimens shall not be removed until after post-weld heat treatment is complete, except for ferritic grades when the post-weld heat treatment is conducted at least 50 °F [30 °C] below the actual tempering temperature. When test blanks are used, they shall receive approximately the same working as the finished product. The test blanks shall be heat treated with the finished product and shall approximate the maximum cross section of the forgings they represent.

8.3 For normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall correspond to the ¼ *T* plane or deeper position where *T* is the maximum heat-treated thickness of the represented forging. In addition, for quenched and tempered forgings, the mid-length of the test specimen shall be at least *T* from any second heat-treated surface. When the section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location, as agreed to by the purchaser and the supplier.

8.3.1 With prior purchase approval, the test specimen for ferritic steel forgings may be taken at a depth (*t*) corresponding to the distance from the area of significant stress to the nearest heat-treated surface and at least twice this distance (2 *t*) from any second surface. However, the test depth shall not be nearer to one treated surface than ¾ in. [19 mm] and to the second treated surface than 1½ in. [38 mm]. This method of test specimen location would normally apply to contour-forged parts, or parts with thick cross-sectional areas where ¼ $T \times T$ testing (see 8.3) is not practical. Sketches showing the exact test locations shall be approved by the purchaser when this method is used.

8.3.2 *Metal Buffers*—The required distances from heat-treated surfaces may be obtained with metal buffers instead of integral extensions. Buffer material may be carbon or low-alloy steel, and shall be joined to the forging with a partial penetration weld that seals the buffered surface. Specimens shall be located at ½-in. [13-mm] minimum from the buffered surface of the forging. Buffers shall be removed and the welded areas subjected to magnetic particle test to ensure freedom from cracks unless the welded areas are completely removed by subsequent machining.

8.4 For annealed low alloy steels, ferritic stainless steels, and martensitic stainless steels, and also for austenitic and ferritic-austenitic stainless steels, the test specimen may be taken from any convenient location.

8.5 *Tension Tests*:

8.5.1 *Low Alloy Steels and Ferritic and Martensitic Stainless Steels*—One tension test shall be made for each heat in each heat treatment charge.

8.5.1.1 When the heat-treating cycles are the same and the furnaces (either batch or continuous type) are controlled within ±25 °F [±14 °C] and equipped with recording pyrometers so that complete records of heat treatment are available, then only one tension test from each heat of each forging type (see Note 1) and section size is required, instead of one test from each heat in each heat-treatment charge.

NOTE 1—“Type” in this case is used to describe the forging shape such as a flange, ell, tee, and the like.

8.5.2 *Austenitic and Ferritic-Austenitic Stainless Steel Grades*—One tension test shall be made for each heat.

8.5.2.1 When heat treated in accordance with 6.1, the test blank or forging used to provide the test specimen shall be heat treated with a finished forged product.

8.5.2.2 When the alternative method in 6.3.1 is used, the test blank or forging used to provide the test specimen shall be forged and quenched under the same processing conditions as the forgings they represent.

8.5.3 Testing shall be performed in accordance with Test Methods and Definitions A 370 using the largest feasible of the round specimens. The gage length for measuring elongation shall be four times the diameter of the test section.

8.6 *Hardness Tests*:

8.6.1 Except when only one forging is produced, a minimum of two pieces per batch or continuous run as defined in 8.6.2 shall be hardness tested in accordance with Test Methods and Definitions A 370 to ensure that the forgings are within the hardness limits given for each grade in Table 3. The purchaser may verify that the requirement has been met by testing at any location on the forging provided such testing does not render the forging useless.

8.6.2 When the reduced number of tension tests permitted by 8.5.1.1 is applied, additional hardness tests shall be made on forgings or samples, as defined in 8.2, scattered throughout the load (see Note 2). At least eight samples shall be checked from each batch load, and at least one check per hour shall be made from a continuous run. When the furnace batch is less than eight forgings, each forging shall be checked. If any check falls outside the prescribed limits, the entire lot of forgings shall be reheat treated and the requirements of 8.5.1 shall apply.

NOTE 2—The tension test required in 8.5.1 is used to determine material capability and conformance in addition to verifying the adequacy of the heat-treatment cycle. Additional hardness tests in accordance with 8.6.2 are required when 8.5.1.1 is applied to ensure the prescribed heat-treating cycle and uniformity throughout the load.

8.7 *Notch Toughness Requirements*—Grades F 3V, F 3VCb, and F 22V.

8.7.1 Impact test specimens shall be Charpy V-notch Type, as shown in Fig. 11a of Test Methods and Definitions A 370. The usage of subsize specimens due to material limitations must have prior purchaser approval.

TABLE 2 Chemical Requirements[A]

Identification Symbol	UNS Designation	Grade	Composition, %: Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
			Low Alloy Steels										
F 1	K12822	carbon-molybdenum	0.28	0.60–0.90	0.045	0.045	0.15–0.35			0.44–0.65			
F 2[B]	K12122	0.5 % chromium, 0.5 % molybdenum	0.05–0.21	0.30–0.80	0.040	0.040	0.10–0.60		0.50–0.81	0.44–0.65			
F 5[C]	K41545	4 to 6 % chromium	0.15	0.30–0.60	0.030	0.030	0.50	0.50	4.0–6.0	0.44–0.65			
F 5a[C]	K42544	4 to 6 % chromium	0.25	0.60	0.040	0.030	0.50	0.50	4.0–6.0	0.44–0.65			
F 9	K90941	9 % chromium	0.15	0.30–0.60	0.030	0.030	0.50–1.00		8.0–10.0	0.90–1.10			
F 10	S33100	20 nickel, 8 chromium	0.10–0.20	0.50–0.80	0.040	0.030	1.00–1.40	19.0–22.0	7.0–9.0				
F 91	K90901	9 % chromium, 1 % molybdenum, 0.2 % vanadium plus columbium and nitrogen	0.08–0.12	0.30–0.60	0.020	0.010	0.20–0.50	0.40	8.0–9.5	0.85–1.05	0.06–0.10		N 0.03–0.07 Al 0.02[D] V 0.18–0.25 Ti 0.01[D] Zr 0.01[D]
F 92	K92460	9 % chromium, 1.8 % tungsten, 0.2 % vanadium plus columbium	0.07–0.13	0.30–0.60	0.020	0.010	0.50	0.40	8.50–9.50	0.30–0.60	0.04–0.09		V 0.15–0.25 N 0.030–0.070 Al 0.02[D] W 1.50–2.00 B 0.001–0.006 Ti 0.01[D] Zr 0.01[D]
F 122	K91271	11 % chromium, 2 % tungsten, 0.2 % vanadium, plus molybdenum, columbium, copper, nickel, nitrogen, and boron	0.07–0.14	0.70	0.020	0.010	0.50	0.50	10.00–11.50	0.25–0.60	0.04–0.10		V 0.15–0.30 B 0.005 N 0.040–0.100 Al 0.02[D] Cu 0.30–1.70 W 1.50–2.50 Ti 0.01[D] Zr 0.01[D]
F 911	K91061	9 % chromium, 1 % molybdenum, 0.2 % vanadium plus columbium and nitrogen	0.09–0.13	0.30–0.60	0.020	0.010	0.10–0.50	0.40	8.5–9.5	0.90–1.10	0.060–0.10		W 0.90–1.10 Al 0.02[D] N 0.04–0.09 V 0.18–0.25 B 0.0003–0.006 Ti 0.01[D] Zr 0.01[D]
F 11 Class 1	K11597	1.25 % chromium, 0.5 % molybdenum	0.05–0.15	0.30–0.60	0.030	0.030	0.50–1.00		1.00–1.50	0.44–0.65			
F 11 Class 2	K11572	1.25 % chromium, 0.5 % molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.50–1.00		1.00–1.50	0.44–0.65			
F 11 Class 3	K11572	1.25 % chromium, 0.5 % molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.50–1.00		1.00–1.50	0.44–0.65			
F 12 Class 1	K11562	1 % chromium, 0.5 % molybdenum	0.05–0.15	0.30–0.60	0.045	0.045	0.50 max		0.80–1.25	0.44–0.65			
F 12 Class 2	K11564	1 % chromium, 0.5 % molybdenum	0.10–0.20	0.30–0.80	0.040	0.040	0.10–0.60		0.80–1.25	0.44–0.65			
F 21	K31545	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50 max		2.7–3.3	0.80–1.06			

TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 3V	K31830	3 % chromium, 1 % molybdenum, 0.25 % vanadium plus boron and titanium	0.05–0.18	0.30–0.60	0.020	0.020	0.10		2.8–3.2	0.90–1.10		0.015–0.035	V 0.20–0.30 B 0.001–0.003
F 3VCb	K31390	3 % chromium, 1 % molybdenum, 0.25 % vanadium plus boron, columbium, and titanium	0.10–0.15	0.30–0.60	0.020	0.010	0.10	0.25	2.7–3.3	0.90–1.10	0.015–0.070	0.015	V 0.20–0.30 Cu 0.25 Ca 0.0005–0.0150
F 22 Class 1	K21590	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50		2.00–2.50	0.87–1.13			
F 22 Class 3	K21590	chromium-molybdenum	0.05–0.15	0.30–0.60	0.040	0.040	0.50		2.00–2.50	0.87–1.13			
F 22V	K31835	2.25 % chromium, 1 % molybdenum, 0.25 % vanadium	0.11–0.15	0.30–0.60	0.015	0.010	0.10	0.25	2.00–2.50	0.90–1.10	0.07	0.030	Cu 0.20 V 0.25–0.35 B 0.002 Ca 0.015^{E}
F 23	K41650	2.25 % chromium, 1.6 % tungsten, 0.25 % vanadium, plus molybdenum, columbium, and boron	0.04–0.10	0.10–0.60	0.030	0.010	0.50		1.90-2.60	0.05-0.30	0.02–0.08		V 0.20–0.30 B 0.0005–0.006 N 0.030 Al 0.030 W 1.45–1.75
F 24	K30736	2.25 % chromium, 1 % molybdenum, 0.25 % vanadium plus titanium and boron	0.05–0.10	0.30–0.70	0.020	0.010	0.15–0.45		2.20–2.60	0.90–1.10		0.06-0.10	V 0.20–0.30 N 0.12 Al 0.020 B 0.0015–0.0070
FR	K22035	2 % nickel, 1 % copper	0.20	0.40–1.06	0.045	0.050		1.60–2.24					Cu 0.75–1.25
F 36	K21001	1.15 % nickel, 0.65 % copper, molybdenum, and columbium	0.10–0.17	0.80–1.20	0.030	0.025	0.25–0.50	1.00–1.30	0.30	0.25–0.50	0.015–0.045		N 0.020 Al 0.050 Cu 0.50–0.80 V 0.02
Martensitic Stainless Steels													
F 6a	S41000	13 % chromium 410^{F}	0.15	1.00	0.040	0.030	1.00	0.50	11.5–13.5				
F 6b	S41026	13 % chromium, 0.5 % molybdenum	0.15	1.00	0.020	0.020	1.00	1.00–2.00	11.5–13.5	0.40–0.60			Cu 0.50
F 6NM	S41500	13 % chromium, 4 % nickel	0.05	0.50–1.00	0.030	0.030	0.60	3.5–5.5	11.5–14.0	0.50–1.00			
Ferritic Stainless Steels													
F XM-27Cb^{G}	S44627	27 chromium, 1 molybdenum XM-27^{F}	0.010	0.40	0.020	0.020	0.40	0.50	25.0–27.5	0.75–1.50	0.05–0.20		N 0.015 Cu 0.20
F 429	S42900	15 chromium 429^{F}	0.12	1.00	0.040	0.030	0.75	0.50	14.0–16.0				
F 430	S43000	17 chromium 430^{F}	0.12	1.00	0.040	0.030	0.75	0.50	16.0–18.0				
Austenitic Stainless Steels													
F 304^{H}	S30400	18 chromium, 8 nickel 304^{F}	0.08	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0				

TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 304H	S30409	18 chromium, 8 nickel 304H[F]	0.04–0.10	2.00	0.045	0.030	1.00	8.0–11.0	18.0–20.0				
F 304L[H]	S30403	18 chromium, 8 nickel, low carbon 304L[F]	0.030	2.00	0.045	0.030	1.00	8.0–13.0	18.0–20.0				
F 304N[I]	S30451	18 chromium, 8 nickel, modified with nitrogen 304N[F]	0.08	2.00	0.045	0.030	1.00	8.0–10.5	18.0–20.0				
F 304LN[I]	S30453	18 chromium, 8 nickel, modified with nitrogen 304LN[F]	0.030	2.00	0.045	0.030	1.00	8.0–10.5	18.0–20.0				
F 309H	S30909	23 chromium, 13.5 nickel 309H[F]	0.04–0.10	2.00	0.045	0.030	1.00	12.0–15.0	22.0–24.0				
F 310	S31000	25 chromium, 20 nickel 310[F]	0.25	2.00	0.045	0.030	1.00	19.0–22.0	24.0–26.0				
F 310H	S31009	25 chromium, 20 nickel 310H[F]	0.04–0.10	2.00	0.045	0.030	1.00	19.0–22.0	24.0–26.0				
F 310MoLN	S31050	25 chromium, 22 nickel, modified with molybdenum and nitrogen, low carbon 310MoLN[F]	0.030	2.00	0.030	0.015	0.40	21.0–23.0	24.0–26.0	2.00–3.00			N 0.10–0.16
F 316[H]	S31600	18 chromium, 8 nickel, modified with molybdenum 316[F]	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00			
F 316H	S31609	18 chromium, 8 nickel, modified with molybdenum 316H[F]	0.04–0.10	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00			
F 316L[H]	S31603	18 chromium, 8 nickel, modified with molybdenum, low carbon 316L[F]	0.030	2.00	0.045	0.030	1.00	10.0–15.0	16.0–18.0	2.00–3.00			
F 316N[I]	S31651	18 chromium, 8 nickel, modified with molybdenum and nitrogen 316N[F]	0.08	2.00	0.045	0.030	1.00	11.0–14.0	16.0–18.0	2.00–3.00			
F 316LN[I]	S31653	18 chromium, 8 nickel, modified with molybdenum and nitrogen 316LN[F]	0.030	2.00	0.045	0.030	1.00	11.0–14.0	16.0–18.0	2.00–3.00			
F 316Ti	S31635	18 chromium, 8 nickel, modified with molybdenum and nitrogen 316Ti	0.08	2.00	0.045	0.030	1.00	10.0–14.0	16.0–18.0	2.00–3.00		[J]	N 0.10 max
F 317	S31700	19 chromium, 13 nickel, 3.5 molybdenum 317[F]	0.08	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0			

TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 317L	S31703	19 chromium, 13 nickel, 3.5 molybdenum 317L[F]	0.030	2.00	0.045	0.030	1.00	11.0–15.0	18.0–20.0	3.0–4.0			
F 321	S32100	18 chromium, 8 nickel modified with titanium 321[F]	0.08	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0			[K]	
F 321H	S32109	18 chromium, 8 nickel, modified with titanium 321H[F]	0.04–0.10	2.00	0.045	0.030	1.00	9.0–12.0	17.0–19.0			[L]	
F 347	S34700	18 chromium, 8 nickel modified with columbium 347[F]	0.08	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0		[M]		
F 347H	S34709	18 chromium, 8 nickel, modified with columbium 347H[F]	0.04–0.10	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0		[N]		
F 348	S34800	18 chromium, 8 nickel modified with columbium 348[F]	0.08	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0		[M]		Co 0.20 Ta 0.10
F 348H	S34809	18 chromium, 8 nickel, modified with columbium 348H[F]	0.04–0.10	2.00	0.045	0.030	1.00	9.0–13.0	17.0–20.0		[N]		Co 0.20 Ta 0.10
F XM-11	S21904	20 chromium, 6 nickel, 9 manganese XM-11[F]	0.040	8.0–10.0	0.060	0.030	1.00	5.5–7.5	19.0–21.5				N 0.15–0.40
F XM-19	S20910	22 chromium, 13 nickel, 5 manganese XM-19[F]	0.06	4.0–6.0	0.040	0.030	1.00	11.5–13.5	20.5–23.5	1.50–3.00	0.10–0.30		N 0.20–0.40 V 0.10–0.30
F 20	N08020	35 nickel, 20 chromium, 3.5 copper, 2.5 molybdenum	.07	2.00	0.045	0.035	1.00	32.0–38.0	19.0–21.0	2.00–3.00	8xCmin–1.00		Cu 3.0–4.0
F 44	S31254	20 chromium, 18 nickel, 6 molybdenum, low carbon	0.020	1.00	0.030	0.010	0.80	17.5–18.5	19.5–20.5	6.0–6.5			Cu 0.50–1.00 N 0.18–0.22
F 45	S30815	21 chromium, 11 nickel modified with nitrogen and cerium	0.05–0.10	0.80	0.040	0.030	1.40–2.00	10.0–12.0	20.0–22.0				N 0.14–0.20 Ce 0.03–0.08
F 46	S30600	18 chromium, 15 nickel, 4 silicon	0.018	2.00	0.020	0.020	3.7–4.3	14.0–15.5	17.0–18.5	0.20			Cu 0.50
F 47	S31725	19 chromium, 15 nickel, 4 molybdenum 317LM[F]	0.030	2.00	0.045	0.030	0.75	13.0–17.5	18.0–20.0	4.0–5.0			N 0.10
F 48	S31726	19 chromium, 15 nickel, 4 molybdenum 317LMN[F]	0.030	2.00	0.045	0.030	0.75	13.5–17.5	17.0–20.0	4.0–5.0			N 0.10–0.20
F 49	S34565	24 chromium, 17 nickel, 6 manganese, 5 molybdenum	0.030	5.0–7.0	0.030	0.010	1.00	16.0–18.0	23.0–25.0	4.0–5.0	0.10		N 0.40–0.60
F 56	S33228	32 nickel, 27 chromium with columbium	0.04–0.08	1.00	0.020	0.015	0.30	31.0–33.0	26.0–28.0		0.6–1.0		Ce 0.05–0.10 Al 0.025

TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 58	S31266	24 chromium, 20 nickel, 6 molybdenum, 2 tungsten with nitrogen	0.030	2.0–4.0	0.035	0.020	1.00	21.0–24.0	23.0–25.0	5.2–6.2			N 0.35–0.60 Cu 1.00–2.50 W 1.50–2.50
F 62	N08367	21 chromium, 25 nickel, 6.5 molybdenum	0.030	2.00	0.040	0.030	1.00	23.5–25.5	20.0–22.0	6.0–7.0			N 0.18–0.25 Cu 0.75
F 63	S32615	18 chromium, 20 nickel, 5.5 silicon	0.07	2.00	0.045	0.030	4.8-6.0	19.0-22.0	16.5-19.5	0.30-1.50			Cu 1.50-2.50
F 64	S30601	17.5 chromium, 17.5 nickel, 5.3 silicon	0.015	0.50-0.80	0.030	0.013	5.0-5.6	17.0-18.0	17.0-18.0	0.20			Cu 0.35, N 0.05
F 904L	N08904	21 chromium, 26 nickel, 4.5 molybdenum 904L[F]	0.020	2.0	0.040	0.030	1.00	23.0–28.0	19.0–23.0	4.0–5.0			Cu 1.00–2.00 N 0.10
						Ferritic-Austenitic Stainless Steels							
F 50	S31200	25 chromium, 6 nickel, modified with nitrogen	0.030	2.00	0.045	0.030	1.00	5.5–6.5	24.0–26.0	1.20–2.00			N 0.14–0.20
F 51	S31803	22 chromium, 5.5 nickel, modified with nitrogen	0.030	2.00	0.030	0.020	1.00	4.5–6.5	21.0–23.0	2.5–3.5			N 0.08–0.20
F 52	S32950	26 chromium, 3.5 nickel, 1.0 molybdenum	0.030	2.00	0.035	0.010	0.60	3.5–5.2	26.0–29.0	1.00–2.50			N 0.15–0.35
F 53	S32750	25 chromium, 7 nickel, 4 molybdenum, modified with nitrogen 2507[F]	0.030	1.20	0.035	0.020	0.80	6.0–8.0	24.0–26.0	3.0–5.0			N 0.24–0.32 Cu 0.50
F 54	S39274	25 chromium, 7 nickel, modified with nitrogen and tungsten	0.030	1.00	0.030	0.020	0.80	6.0–8.0	24.0–26.0	2.5–3.5			N 0.24–0.32 Cu 0.20–0.80 W 1.50–2.50
F 55	S32760	25 chromium, 7 nickel, 3.5 molybdenum, modified with nitrogen and tungsten	0.030	1.00	0.030	0.010	1.00	6.0–8.0	24.0–26.0	3.0–4.0			N 0.20–0.30 Cu 0.50–1.00 W 0.50–1.00[O]
F 57	S39277	26 chromium, 7 nickel, 3.7 molybdenum	0.025	0.80	0.025	0.002	0.80	6.5–8.0	24.0–26.0	3.0–4.0			Cu 1.20–2.00 W 0.80–1.20 N 0.23–0.33
F 59	S32520	25 chromium, 6.5 nickel, 4 molybdenum with nitrogen	0.030	1.50	0.035	0.020	0.80	5.5–8.0	24.0–26.0	3.0–5.0			N 0.20–0.35 Cu 0.50–3.00
F 60	S32205	22 chromium, 5.5 nickel, 3 molybdenum, modified with nitrogen 2205[F]	0.030	2.00	0.030	0.020	1.00	4.5–6.5	22.0–23.0	3.0–3.5			N 0.14–0.20

TABLE 2 *Continued*

Identification Symbol	UNS Designation	Grade	Composition, %										
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Columbium	Titanium	Other Elements
F 61	S32550	26 chromium, 6 nickel, 3.5 molybdenum with nitrogen and copper 255[F]	0.040	1.50	0.040	0.030	1.00	4.5–6.5	24.0–27.0	2.9–3.9			Cu 1.50–2.50 N 0.10–0.25
F 65	S32906	29 chromium, 6.5 nickel, 2 molybdenum with nitrogen	0.030	0.80–1.50	0.030	0.030	0.80	5.8–7.5	28.0–30.0	1.5–2.6			Cu 0.80 N 0.30–0.40

[A] All values are maximum unless otherwise stated.
[B] Grade F 2 was formerly assigned to the 1 % chromium, 0.5 % molybdenum grade which is now Grade F 12.
[C] The present grade F 5a (0.25 max carbon) previous to 1955 was assigned the identification symbol F 5. Identification symbol F 5 in 1955 was assigned to the 0.15 max carbon grade to be consistent with ASTM specifications for other products such as pipe, tubing, bolting, welding fittings, and the like.
[D] Applies to both heat and product analyses.
[E] For Grade F22V, rare earth metals (REM) may be added in place of calcium, subject to agreement between the producer and the purchaser. In that case the total amount of REM shall be determined and reported.
[F] Naming system developed and applied by ASTM.
[G] Grade F XM-27Cb shall have a nickel plus copper content of 0.50 max %. Product analysis tolerance over the maximum specified limit for carbon and nitrogen shall be 0.002 %.
[H] Grades F 304, F 304L, F 316, and F 316L shall have a maximum nitrogen content of 0.10 %.
[I] Grades F 304N, F 316N, F 304LN, and F 316LN shall have a nitrogen content of 0.10 to 0.16 %.
[J] Grade F 316Ti shall have a titanium content not less than five times the carbon plus nitrogen content and not more than 0.70 %.
[K] Grade F 321 shall have a titanium content of not less than five times the carbon content and not more than 0.70 %.
[L] Grade F 321H shall have a titanium content of not less than four times the carbon content and not more than 0.70 %.
[M] Grades F 347 and F 348 shall have a columbium content of not less than ten times the carbon content and not more than 1.10 %.
[N] Grades F 347H and F 348H shall have a columbium content of not less than eight times the carbon content and not more than 1.10 %.
[O] % Cr + 3.3 × % Mo + 16 × % N = 40 min.

TABLE 3 Tensile and Hardness Requirements

Grade Symbol	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa][A]	Elongation in 2 in. [50 mm] or 4*D*, min, %	Reduction of Area, min, %	Brinell Hardness Number
		Low Alloy Steels			
F 1	70 [485]	40 [275]	20	30	143–192
F 2	70 [485]	40 [275]	20	30	143–192
F 5	70 [485]	40 [275]	20	35	143–217
F 5a	90 [620]	65 [450]	22	50	187–248
F 9	85 [585]	55 [380]	20	40	179–217
F 10	80 [550]	30 [205]	30	50	. . .
F 91	85 [585]	60 [415]	20	40	248 max
F 92	90 [620]	64 [440]	20	45	269 max
F 122	90 [620]	58 [400]	20	40	250 max
F 911	90 [620]	64 [440]	18	40	187–248
F 11 Class 1	60 [415]	30 [205]	20	45	121–174
F 11 Class 2	70 [485]	40 [275]	20	30	143–207
F 11 Class 3	75 [515]	45 [310]	20	30	156–207
F 12 Class 1	60 [415]	32 [220]	20	45	121–174
F 12 Class 2	70 [485]	40 [275]	20	30	143–207
F 21	75 [515]	45 [310]	20	30	156–207
F 3V, and F 3VCb	85–110 [585–760]	60 [415]	18	45	174–237
F 22 Class 1	60 [415]	30 [205]	20	35	170 max
F 22 Class 3	75 [515]	45 [310]	20	30	156–207
F 22V	85–110 [585–780]	60 [415]	18	45	174–237
F 23	74 [510]	58 [400]	20	40	220 max
F 24	85 [585]	60 [415]	20	40	248 max
FR	63 [435]	46 [315]	25	38	197 max
F 36, Class 1	90 [620]	64 [440]	15	. . .	252 max
F 36, Class 2	95.5 [660]	66.5 [460]	15	. . .	252 max
		Martensitic Stainless Steels			
F 6a Class 1	70 [485]	40 [275]	18	35	143–207
F 6a Class 2	85 [585]	55 [380]	18	35	167–229
F 6a Class 3	110 [760]	85 [585]	15	35	235–302
F 6a Class 4	130 [895]	110 [760]	12	35	263–321
F 6b	110–135 [760–930]	90 [620]	16	45	235–285
F 6NM	115 [790]	90 [620]	15	45	295 max
		Ferritic Stainless Steels			
F XM-27Cb	60 [415]	35 [240]	20	45	190 max
F 429	60 [415]	35 [240]	20	45	190 max
F 430	60 [415]	35 [240]	20	45	190 max
		Austenitic Stainless Steels			
F 304	75 [515][B]	30 [205]	30	50	. . .
F 304H	75 [515][B]	30 [205]	30	50	. . .
F 304L	70 [485][C]	25 [170]	30	50	. . .
F 304N	80 [550]	35 [240]	30[D]	50[E]	. . .
F 304LN	75 [515][B]	30 [205]	30	50	. . .
F 309H	75 [515][B]	30 [205]	30	50	. . .
F 310	75 [515][B]	30 [205]	30	50	. . .
F 310 MoLN	78 [540]	37 [255]	25	40	. . .
F 310H	75 [515][B]	30 [205]	30	50	. . .
F 316	75 [515][B]	30 [205]	30	50	. . .
F 316H	75 [515][B]	30 [205]	30	50	. . .
F 316L	70 [485][C]	25 [170]	30	50	. . .
F 316N	80 [550]	35 [240]	30[D]	50[E]	. . .
F 316LN	75 [515][B]	30 [205]	30	50	. . .
F 316Ti	75 [515]	30 [205]	30	40	. . .
F 317	75 [515][B]	30 [205]	30	50	. . .
F 317L	70 [485][C]	25 [170]	30	50	. . .
F 347	75 [515][B]	30 [205]	30	50	. . .
F 347H	75 [515][B]	30 [205]	30	50	. . .
F 348	75 [515][B]	30 [205]	30	50	. . .
F 348H	75 [515][B]	30 [205]	30	50	. . .
F 321	75 [515][B]	30 [205]	30	50	. . .
F 321H	75 [515][B]	30 [205]	30	50	. . .
F XM-11	90 [620]	50 [345]	45	60	. . .
F XM-19	100 [690]	55 [380]	35	55	. . .
F 20	80 [550]	35 [240]	30	50	. . .
F 44	94 [650]	44 [300]	35	50	. . .

TABLE 3 *Continued*

Grade Symbol	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]^A	Elongation in 2 in. [50 mm] or 4*D*, min, %	Reduction of Area, min, %	Brinell Hardness Number
F 45	87 [600]	45 [310]	40	50	. . .
F 46	78 [540]	35 [240]	40	50	. . .
F 47	75 [525]	30 [205]	40	50	. . .
F 48	80 [550]	35 [240]	40	50	. . .
F 49	115 [795]	60 [415]	35	40	. . .
F 56	73 [500]	27 [185]	30	35	. . .
F 58	109 [750]	61 [420]	35	50	. . .
F 62	95 [655]	45 [310]	30	50	. . .
F 63	80 [550]	32 [220]	25	. . .	192 max
F 64	90 [620]	40 [275]	35	50	217 max
F 904L	71 [490]	31 [215]	35	. . .	. . .
Ferritic-Austenitic Stainless Steels					
F 50	100–130 [690–900]	65 [450]	25	50	. . .
F 51	90 [620]	65 [450]	25	45	. . .
F 52	100 [690]	70 [485]	15	. . .	. . .
F 53	116 [800]^F	80 [550]^F	15	. . .	310 max
F 54	116 [800]	80 [550]	15	30	310 max
F 55	109–130 [750–895]	80 [550]	25	45	. . .
F 57	118 [820]	85 [585]	25	50	. . .
F 59	112 [770]	80 [550]	25	40	. . .
F 60	95 [655]	65 [450]	25	45	. . .
F 61	109 [750]	80 [550]	25	50	. . .
F 65	109 [750]	80 [550]	25	. . .	. . .

^{A} Determined by the 0.2 % offset method. For ferritic steels only, the 0.5 % extension-under-load method may also be used.
^{B} For sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 70 ksi [485 MPa].
^{C} For sections over 5 in. [130 mm] in thickness, the minimum tensile strength shall be 65 ksi [450 MPa].
^{D} Longitudinal. The transverse elongation shall be 25 % in 2 in. or 50 mm, min.
^{E} Longitudinal. The transverse reduction of area shall be 45 % min.
^{F} For sections over 2 in. [50 mm] in thickness, the minimum tensile strength shall be 106 ksi [730 MPa]; the minimum yield strength shall be 75 ksi [515 MPa].

8.7.2 The Charpy V-notch test specimens shall be obtained as required for tension tests in 8.2, 8.3 and 8.5. One set of three Charpy V-notch specimens shall be taken from each tensile specimen location.

8.7.3 The longitudinal axis and mid-length of impact specimen shall be located similarly to the longitudinal axis of the tension test specimens. The axis of the notch shall be normal to the nearest heat-treated surface of the forging.

8.7.4 The Charpy V-notch tests shall meet a minimum energy absorption value of 40 ft-lbf [54 J] average of three specimens. One specimen only in one set may be below 40 ft-lbf [54 J], and it shall meet a minimum value of 35 ft-lbf [48 J].

8.7.5 The impact test temperature shall be 0 °F [−18 °C].

9. Grain Size for Austenitic Grades

9.1 All H grades and grade F 63 shall be tested for average grain size by Test Methods E 112.

9.1.1 Grades F 304H, F 309H, F 310H, and F 316H shall have a grain size of ASTM No. 6 or coarser.

9.1.2 Grades F 321H, F 347H, and F 348H shall have a grain size of ASTM No. 7 or coarser.

9.1.3 Grade F 63 shall have a grain size of ASTM No. 3 or finer.

10. Corrosion Testing for Austenitic Grades

10.1 Corrosion testing is not required by this specification.

10.2 Austenitic grades shall be capable of meeting the intergranular corrosion test requirements described in Supplementary Requirement S4.

11. Retreatment

11.1 If the results of the mechanical tests do not conform to the requirements specified, the manufacturer may reheat treat the forgings and repeat the tests specified in Section 8.

12. Workmanship, Finish, and Appearance

12.1 Forgings shall conform to the requirements of Specification A 961/A 961M.

12.2 The forgings shall be free of scale, machining burrs which might hinder fit-up, and other injurious imperfections as defined herein. The forgings shall have a workmanlike finish, and machined surfaces (other than surfaces having special requirements) shall have a surface finish not to exceed 250 AA (arithmetic average) roughness height.

13. Repair by Welding

13.1 Weld repairs shall be permitted (see Supplementary Requirement S9 of Specification A 961/A 961M) at the discretion of the manufacturer with the following limitations and requirements:

13.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

13.1.2 The weld metal shall be deposited using the electrodes specified in Table 4 except as otherwise provided in

Supplementary Requirement S5. The electrodes shall be purchased in accordance with ASME Specifications SFA-5.4, SFA-5.5, SFA-5.9, or SFA-5.11. The submerged arc process with neutral flux, the gas metal-arc process, the gas tungsten-arc process, and gas shielded processes using flux-core consumables, may be used.

13.1.3 Defects shall be completely removed prior to welding by chipping or grinding to sound metal as verified by magnetic-particle inspection in accordance with Test Method A 275/A 275M for the low alloy steels and ferritic, martensitic, or ferritic-austenitic stainless steels, or by liquid-penetrant inspection in accordance with Test Method E 165 for all grades.

13.1.4 After repair welding, the welded area shall be ground smooth to the original contour and shall be completely free of defects as verified by magnetic-particle or liquid-penetrant inspection, as applicable.

13.1.5 The preheat, interpass temperature, and post-weld heat treatment requirements given in Table 4 shall be met. Austenitic stainless steel forgings may be repair-welded without the post-weld heat treatment of Table 4, provided purchaser approval is obtained prior to repair.

13.1.6 Repair by welding shall not exceed 10 % of the surface area of the forging nor 33⅓ % of the wall thickness of the finished forging or ⅜ in. [9.5 mm], whichever is less, without prior approval of the purchaser.

13.1.7 When approval of the purchaser is obtained, the limitations set forth in 13.1.6 may be exceeded, but all other requirements of Section 13 shall apply.

13.1.8 No weld repairs are permitted for F 6a Classes 3 and 4.

13.1.9 Post-weld heat treatment times for F 36 are: for Class 1, up to 2 in. [50 mm] in thickness, 1 h per in. [25 mm], 15 minutes minimum, and over 2 in. [50 mm], 15 minutes for each additional in. of thickness or fraction thereof; for Class 2, 1 h per in. [25 mm], ½ h minimum.

TABLE 4 Repair Welding Requirements

Grade Symbol	Electrodes[A]	Recommended Preheat and Interpass Temperature Range, °F [°C]	Post Weld Heat-Treatment Temperature, Minimum or Range, °F [°C]
		Low Alloy Steels	
F 1	E 7018-A 1	200–400 [95–205]	1150 [620]
F 2	E 8018-B 1	300–600 [150–315]	1150 [620]
F 5	E 502-15 or 16	400–700 [205–370]	1250 [675]
F 5a	E 502-15 or 16	400–700 [205–370]	1250 [675]
F 9	E 505-15 or 16	400–700 [205–370]	1250 [675]
F 10[B]	. . .	. . .	. . .
F 91	9 % Cr, 1 % Mo, VCbN	400–700 [205–370]	1350–1470 [730–800]
F 92	9 % Cr, 0.5 % Mo, 1.5 % W, VCbNiN	400–700 [205–370]	1350–1470 [730–800]
F 122	11 % Cr, 2 % W, MoVCbCuN	400–700 [205–370]	1350–1470 [730–800]
F 911	9 % Cr, 1 % Mo, 1 % W, VCbN	400–700 [205–370]	1365–1435 [740–780]
F 11, Class 1, 2, and 3	E 8018-B 2	300–600 [150–315]	1150 [620]
F 12, Class 1 and 2	E 8018-B 2	300–600 [150–315]	1150 [620]
F 21	E 9018-B 3	300–600 [150–315]	1250 [675]
F 3V, and F 3VCb	3 % Cr, 1 % Mo, ¼ % V-Ti	300–600 [150–315]	1250 [675]
F 22 Class 1	E 9018-B 3	300–600 [150–315]	1250 [675]
F 22 Class 3	E 9018-B 3	300–600 [150–315]	1250 [675]
F 22V	2.25 % Cr, 1 % Mo, 0.25 % V-Cb	300–600 [150–315]	1250 [675]
F 23	2.25 % Cr, 1.6 % W, 0.25 % V-Mo-Cb-B	300-600 [150–315]	1350–1470 [730–800]
F 24	2.25 % Cr, 1 % Mo, 0.25 % V	200–400 [95–205][C]	1350–1470 [730–800][C]
F 36, Class 1	1.15 Ni, 0.65 Cu, Mo, Cb	400–700 [205–370]	1100–1200 [595–650]
F 36, Class 2	1.15 Ni, 0.65 Cu, Mo, Cb	400–700 [205–370]	1000–1150 [540–620]
		Martensitic Stainless Steels	
F 6a, Class 1	E 410-15 or 16	400–700 [205–370]	1250 [675]
F 6a, Class 2	E 410-15 or 16	400–700 [205–370]	1250 [675]
F 6b	13 % Cr, 1½ % Ni, ½ % Mo	400–700 [205–370]	1150 [620]
F 6NM	13 % Cr, 4 % Ni	300–700 [150–370]	1050 [565]
		Ferritic Stainless Steels	
F XM-27Cb	26 % Cr, 1 % Mo	NR[D]	NR
F 429	E 430-16	400–700 [205–370]	1400 [760]
F 430	E 430-16	NR	1400 [760]
FR	E 8018-C2	NR	NR
		Austenitic Stainless Steels	
F 304	E 308-15 or 16	NR	1900 [1040] + WQ[E]
F 304L	E 308L-15 or 16	NR	1900 [1040] + WQ
F 304H	E 308-15 or 16	NR	1900 [1040] + WQ
F 304N	E 308-15 or 16	NR	1900 [1040] + WQ

TABLE 4 *Continued*

Grade Symbol	Electrodes[A]	Recommended Preheat and Interpass Temperature Range, °F [°C]	Post Weld Heat-Treatment Temperature, Minimum or Range, °F [°C]
F 304LN	E 308L-15 or 16	NR	1900 [1040] + WQ
F 309H	E 309-15 or 16[F]	NR	1900 [1040] + WQ
F 310	E 310-15 or 16	NR	1900 [1040] + WQ
F 310H	E 310-15 or 16	NR	1900 [1040] + WQ
F 310MoLN	E 310Mo-15 or 16	NR	1920–2010 [1050–1100] + WQ
F 316	E 316-15 or 16	NR	1900 [1040] + WQ
F 316L	E 316L-15 or 16	NR	1900 [1040] + WQ
F 316H	E 316-15 or 16	NR	1900 [1040] + WQ
F 316N	E 316-15 or 16	NR	1900 [1040] + WQ
F 316LN	E 316L-15 or 16	NR	1900 [1040] + WQ
F 316Ti	E 316-15 or 16	NR	1900 [1040] + WQ
F 317	E 317-15 or 16	NR	1900 [1040] + WQ
F 317L	E 317L-15 or 16	NR	1900 [1040] + WQ
F 321[B]	E 347-15 or 16	NR	1900 [1040] + WQ
F 321H[B]	E 347-15 or 16	NR	1925 [1050] + WQ
F 347	E 347-15 or 16	NR	1900 [1040] + WQ
F 347H	E 347-15 or 16	NR	1925 [1050] + WQ
F 348	E 347-15 or 16	NR	1900 [1040] + WQ
F 348H	E 347-15 or 16	NR	1925 [1050] + WQ
F XM-11	XM-10W	NR	NR
F XM-19	XM-19W	NR	NR
F 20	E/ER-320, 320LR	NR	1700–1850 [925–1010] + WQ
F 44	E NiCrMo-3	NR	2100 [1150] + WQ
F 45[B]	. . .	. . .	. . .
F 46	. . .	. . .	. . .
F 47	. . .[G]	. . .	2100 [1150] + WQ
F 48	. . .[G]	. . .	2100 [1150] + WQ
F 49	. . .[G]	. . .	2100 [1150] + WQ
F 58	E NiCrMo-10	. . .	2100 [1150] + WQ
F 62	E NiCrMo-3	NR	2025 [1105] + WQ
F 904L	E NiCrMo-3	NR	1920–2100 [1050–1150] + WQ
Ferritic-Austenitic Stainless Steels			
F 50	25 % Cr, 6 % Ni, 1.7 % Mo	NR	NR
F 51	22 % Cr, 5.5 % Ni, 3 % Mo	NR	NR
F 52	26 % Cr, 8 % Ni, 2 % Mo	NR	NR
F 53	25 % Cr, 7 % Ni, 4 % Mo	NR	NR
F 54	25 % Cr, 7 % Ni, 3 % Mo, W	NR	NR
F 55	25 % Cr, 7 % Ni, 3.5 % Mo	NR	NR
F 57	25 % Cr, 7 % Ni, 3 % Mo, 1.5 % Cu, 1 % W	NR	NR
F 59	E Ni CrMo-10	NR	NR
F 60	22 % Cr, 5.5 % Ni, 3 % Mo	NR	NR
F 61	26 % Cr, 9 % Ni, 3.5 % Mo	NR	NR
F 65	29 % Cr, 6.5 % Ni, 2 % Mo	NR	NR

[A] Electrodes shall comply with ASME SFA 5.4, SFA 5.5, and corresponding ER grades of SFA-5.9 or SFA-5.11.

[B] Purchaser approval required.

[C] Not required for not below 0.500 in. [12.7 mm].

[D] NR = not required.

[E] WQ = water quench.

[F] Filler metal shall additionally have 0.04 % minimum carbon.

[G] Match filler metal is available. Fabricators have also used AWS A 5.14, Class ER, NiCrMo-3 and AWS A 5.11, Class E, NiCrMo-3 filler metals.

14. Inspection

14.1 Inspection provisions of Specification A 961/A 961M apply.

15. Rejection and Rehearing

15.1 The purchaser shall comply with the provisions of Specification A 961/A 961M.

16. Certification

16.1 In addition to the certification requirements of Specification A 961/A 961M, test reports shall be furnished to the purchaser or his representative.

16.2 Test reports shall include certification that all requirements of this specification have been met. The specification designation included on test reports shall include year of issue and revision letter, if any. The manufacturer shall provide the following where applicable:

16.2.1 Type heat treatment, Section 6,

16.2.2 Product analysis results, Section 8 of Specification A 961/A 961M,

16.2.3 Tensile property results, Section 8 (Table 3), report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent,

16.2.4 Chemical analysis results, Section 7 (Table 2), 16.2.5 Hardness results, Section 8 (Table 3),

16.2.6 Grain size results, Section 9, and

16.2.7 Any supplementary testing required by the purchase order.

17. Product Marking

17.1 In addition to the marking requirements of Specification A 961/A 961M, the manufacturer's name (see Note 3) or symbol shall be permanently marked on each forging.

NOTE 3—For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification, and the results have been determined to meet the requirements of this specification.

17.1.1 Quenched and tempered low alloy or martensitic stainless forgings shall be stamped with the letters QT following the specification designation.

17.1.2 Forgings repaired by welding shall be marked with the letter "W" following the Specification designation. When repair-welded austenitic stainless steel forgings have not been postweld heat treated in accordance with Table 4, the letters "WNS" shall be marked following the specification designation.

17.1.3 When test reports are required, the markings shall consist of the manufacturer's symbol or name, the grade symbol, and such other markings as necessary to identify the part with the test report (17.1.1 and 17.1.2 shall apply).

17.1.4 Parts meeting all requirements for more than one class or grade may be marked with more than one class or grade designation such as F 304/F 304H, F 304/F 304L, and the like.

17.2 *Bar Coding*—In addition to the requirements in 17.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

18. Keywords

18.1 austenitic stainless steel; chromium alloy steel; chromium-molybdenum steel; ferritic/austenitic stainless steel; ferritic stainless steel; martensitic stainless steel; nickel alloy steel; notch toughness requirements; pipe fittings; piping applications; pressure containing parts; stainless steel fittings; stainless steel forgings; steel; steel flanges; steel forgings, alloy; steel valves; temperature service applications, elevated; temperature service applications, high; wrought material

SUPPLEMENTARY REQUIREMENTS

In addition to any of the supplementary requirements of Specification A 961/A 961M, the following supplementary requirements shall apply only when specified by the purchaser in the order.

S1. Macroetch Test

S1.1 A sample forging shall be sectioned and etched to show flow lines and internal imperfections. The test shall be conducted according to Test Method E 340. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S2. Heat Treatment Details

S2.1 The manufacturer shall furnish a detailed test report containing the information required in 16.2 and shall include all pertinent details of the heat-treating cycle given the forgings.

S3. Material for Optimum Resistance to Stress-Corrosion Cracking

S3.1 Austenitic stainless steel shall be furnished in the solution-annealed condition as a final operation with no subsequent cold working permitted, except, unless specifically prohibited by the purchaser, straightening of bars from which parts are machined is permitted to meet the requirements of Specification A 484/A 484M.

S4. Corrosion Tests

S4.1 All austenitic stainless steels shall pass intergranular corrosion tests performed in accordance with Practice E of Practices A 262.

S4.2 Intergranular corrosion tests shall be performed on specimens of ferritic stainless steels as described in Practices A 763.

S4.3 For both the austenitic and ferritic stainless steels, details concerning the number of specimens and their source and location are to be a matter of agreement between the manufacturer and the purchaser.

S5. Special Filler Metal

S5.1 In repair-welded F 316, F 316L, F 316H, and F 316N forgings, the deposited weld metal shall conform to E 308 composition wire. Forgings repair welded with E 308 weld metal shall be marked F __ W 308.

S6. Hardness Test

S6.1 Each forging shall be hardness tested and shall meet the requirements of Table 3.

S7. Alternate Heat Treatment (Grade F 91 and F 92)

S7.1 Grade F 91 shall be normalized in accordance with Section 6 and tempered at a temperature, to be specified by the purchaser, less than 1350 °F [730 °C]. It shall be the purchaser's responsibility to subsequently temper at 1350 °F [730 °C] minimum to conform to the requirements of the specification. All mechanical tests shall be made on material heat treated in accordance with Section 6. The certification shall reference this supplementary requirement indicating the tempering temperature applied. The notation "S7"shall be included with the required marking of the forging.

S8. Heat Treatment of Austenitic Forgings

S8.1 The purchaser shall specify the heat-treatment method (in 6.1 or in 6.3.1) that shall be employed.

S8.2 The manufacturer shall provide a test report containing the information required in 16.2 and shall include a statement of the heat-treatment method employed.

S9. Grain Size for Austenitic Grades

S9.1 Forgings made from austenitic grades other than H grades shall be tested for average grain size by Test Method E 112. Details of the test shall be agreed upon between the manufacturer and the purchaser.

S10. Stabilization Treatment

S10.1 Subsequent to the solution anneal for Grades F 321, F 321H, F 347, F 347H, F 348, and F 348H, these grades shall be given a stabilization heat treatment at 1500 to 1600 °F [815 to 870 °C] for a minimum of 2 h/in. [4.7 min/mm] of thickness and then cooling in the furnace or in air. In addition to the marking required in Section 17, the grade designation symbol shall be followed by the symbol "S10."

S11. Grain Size Requirements for Non-H-Grade Austenitic Steels Used Above 1000 °F [540 °C]

S11.1 Non-H grades of austenitic stainless steels shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E 112. The grain size so determined shall be on a certified test report.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 182/A 182M – 07, that may impact the use of this specification. (Approved September 1, 2007)

(*1*) Revised the Yield Strength for Grade F 60 in Table 3.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 182/A 182M – 06, that may impact the use of this specification. (Approved May 1, 2007)

(*1*) Added Grade F 316Ti, S31635, to Tables 1-4
(*2*) Revised chemistry of Grades F 91, F 92, F 911, and F 122 in Table 2.
(*3*) Added grades to direct quench exclusion in 6.3.1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 182/A 182M – 05a, that may impact the use of this specification. (Approved September 1, 2006)

(*1*) Added Grade F 65, UNS 32906, to Tables 1-4.

Designation: A 181/A 181M – 06

Standard Specification for Carbon Steel Forgings, for General-Purpose Piping[1]

This standard is issued under the fixed designation A 181/A 181M; 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*

1.1 This specification[2] covers nonstandard as-forged fittings, valve components, and parts for general service. Forgings made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. Larger forgings may be ordered to Specification A 266/A 266M.

1.2 Two classes of material are covered, designated as Classes 60 and 70, respectively, and are classified in accordance with their mechanical properties as specified in 6.1.

1.3 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

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.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 266/A 266M Specification for Carbon Steel Forgings for Pressure Vessel Components

A 788/A 788M Specification for Steel Forgings, General Requirements

A 961/A 961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

3. General Requirements and Ordering Information

3.1 Product furnished to this specification shall conform to the requirements of Specification A 961/A 961M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 961/A 961M constitutes non-conformance with this specification.

3.2 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include but are not limited to the ordering information in Specification A 961/A 961M and the following:

3.2.1 Supplementary requirements, and

3.2.2 Additional requirements (See 4.3, 9.1, 10.2, 12.1, and 12.2).

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 961/A 961M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 Except for flanges of all types, hollow, cylindrically shaped parts may be machined from hot-rolled or forged bar, provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Other parts, excluding flanges of all types, up to and including NPS 4 may be machined from hot-rolled or forged bar. Elbows, return bends, tees, and header tees shall not be machined directly from bar stock.

4.2 Except as permitted in 4.1, the finished product shall be a forging as defined in the Terminology section (exclusively) of Specification A 788/A 788M.

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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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

Current edition approved Sept. 1, 2006. Published September 2006. Originally approved in 1935. Last previous edition approved in 2001 as A 181/A 181M – 01.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-181 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.

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

4.3 When specified in the order, the manufacturer shall submit for approval of the purchaser a sketch showing the shape of the rough forging before machining.

4.4 Forgings shall be protected against sudden or too rapid cooling from the rolling or forging while passing through the critical range.

4.5 Heat treatment is neither required nor prohibited, but when applied, heat treatment shall consist of tempering, annealing, normalizing, or normalizing and tempering.

5. Chemical Composition

5.1 An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The chemical composition thus determined shall conform to the requirements in Table 1.

6. Mechanical Properties

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

7. Number of Tests

7.1 One tension test shall be made from each heat.

7.2 If any test specimen is defectively machined, it may be discarded and another specimen substituted.

8. Retests

8.1 When one or more representative test specimens do not conform to specification requirements for the tested characteristic, only a single retest for each nonconforming characteristic may be performed to establish product acceptability. Retests shall be performed on twice the number of representative specimens that were originally nonconforming. When any retest specimen does not conform to specification requirements for the characteristic in question, the lot represented by that specimen shall be rejected, heat-treated or reheat-treated in accordance with 4.5, and tested in accordance with Sections 6 and 7.

9. Reports of Testing

9.1 Upon request of the purchaser in the contract or order, a report of the test results and chemical analyses shall be furnished. The specification designation included on reports of testing shall include year of issue and revision letter, if any.

TABLE 1 Chemical Requirements

Element	Composition, % Classes 60 and 70
Carbon, max	0.35
Manganese, max	1.10[A]
Phosphorus, max	0.05
Silicon	0.10-0.35
Sulfur, max	0.05

[A] Manganese may be increased to 1.35 % max provided the carbon is reduced 0.01 % for each 0.06 % increase in manganese over the limit shown in the table.

TABLE 2 Tensile Requirements

	Class 60	Class 70
Tensile strength, min, ksi [MPa]	60 [415]	70 [485]
Yield strength,[A] min, ksi [MPa]	30 [205]	36 [250]
Elongation in 2 in. [50 mm], min, %	22	18
Reduction of area, min, %	35	24

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.

10. Repair by Welding

10.1 Repair welding, by the manufacturer, is permissible for parts made to dimensional standards such as those of ANSI or equivalent standards.

10.2 Prior approval of the purchaser shall be required to weld repair special parts made to the purchaser's requirements.

10.3 The composition of the weld deposits shall be similar to the base metal and in accordance with the procedure qualification for the applicable material. Welding shall be accomplished with a weld procedure designed to produce low hydrogen in the weldment. Short-circuit gas metal arc welding is permissible only with the approval of the purchaser.

11. Marking of Forgings

11.1 Identification marks consisting of the manufacturer's symbol or name, designation of service rating, Specification number, class, and size shall be legibly forged or stamped on each forging, and in such a position as not to injure the usefulness of the forgings.

11.2 *Bar Coding*—In addition to the requirements in 11.1, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts the bar code may be applied to the box or a substantially applied tag.

12. Certificate of Compliance

12.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. The specification designation included on certificates of compliance shall include year of issue and revision letter, if any.

12.2 When specified in the purchase order or contract, a report of the test results shall be furnished.

13. Keywords

13.1 pipe fittings, steel; piping applications; pressure containing parts; steel forgings, carbon; steel valves

SUPPLEMENTARY REQUIREMENTS

S1. Carbon Equivalent

S1.1 The maximum carbon equivalent based on heat analysis shall be as follows:

Class	Maximum Carbon Equivalent Value	
	Maximum Section Thickness Less Than or Equal to 2 in.	Maximum Section Thickness Greater Than 2 in.
60	0.45	0.46
70	0.47	0.48

S1.2 Determine the carbon equivalent (CE) as follows:

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

S1.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

S1.4 When this Supplementary Requirement is invoked, all elements in the carbon equivalent formula shall be analyzed and the amounts reported.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 181/A 181M – 01, that may impact the use of this specification. (Approved September 1, 2006)

(*1*) Deleted old 1.3.
(*2*) Deleted the reference to AIAG standard in Referenced Documents because it no longer applies.
(*3*) Revised 11.1.
(*4*) Updated format and made corrections to agree with the use of Specifications A 788/A 788M and A 961/A 961M.

Designation: A 179/A 179M – 90a (Reapproved 2005)

Used in USNRC-RDT Standards

Standard Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes[1]

This standard is issued under the fixed designation A 179/A 179M; 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 minimum-wall-thickness, seamless cold-drawn low-carbon steel tubes for tubular heat exchangers, condensers, and similar heat transfer apparatus.

1.2 This specification covers tubes ⅛ to 3 in. [3.2 to 76.2 mm], inclusive, in outside diameter.

NOTE 1—Tubing smaller in outside diameter and having a thinner wall than indicated in this specification is available. Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in outside diameter or 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:* [3]

A 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes

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 tubes),

3.1.3 Manufacture (cold-drawn),

3.1.4 Size (outside diameter and minimum wall thickness),

3.1.5 Length (specific or random),

3.1.6 Optional requirements (product analysis, Section 9, flange test, 11.3),

3.1.7 Test report required (Certification Section of Specification A 450/A 450M),

3.1.8 Specification number, and

3.1.9 Special requirements.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M, unless otherwise provided herein.

5. Manufacture

5.1 Tubes shall be made by the seamless process and shall be cold drawn.

6. Heat Treatment

6.1 Tubes shall be heat treated after the final cold draw pass at a temperature of 1200°F [650°C] or higher.

7. Surface Condition

7.1 Finished tubes shall be free of scale. A slight amount of oxidation will not be considered as scale.

8. Chemical Composition

8.1 The steel shall conform to the following requirements as to chemical composition:

Carbon, %	0.06–0.18
Manganese, %	0.27–0.63
Phosphorus, max, %	0.035
Sulfur, max, %	0.035

8.2 Supplying an alloy grade that specifically requires the addition of any element other than those listed in 8.1 is not permitted.

9. Product Analysis

9.1 When requested on the purchase order, a product analysis shall be made by the supplier from 1 tube per 250 pieces or when tubes are identified by heat, one tube per heat shall be

[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 A01.09 on Carbon Steel Tubular Products.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-179 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.

analyzed. The chemical composition thus determined shall conform to the requirements specified.

9.2 If the original test for product analysis fails, retests of two additional billets 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 (Note 2) shall be rejected or, at the option of the producer, each billet or tube may be individually tested for acceptance. Billets or tubes which do not meet the requirements of the specification shall be rejected.

NOTE 2—A lot consists of 250 tubes.

10. Hardness Requirements

10.1 The tubes shall have a hardness number not exceeding 72 HRB.

11. Mechanical Tests Required

11.1 *Flattening Test*—One flattening test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof.

11.2 *Flaring Test*—One flaring test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof.

11.3 *Flange Test*—When specified as a substitute for the flaring test, for tubes having a wall thickness (actual mean wall) less than 10 % of the outside diameter, one test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof. For tubes other than specified above, the flange test shall not be required.

11.4 *Hardness Test*—Rockwell hardness tests shall be made on specimens from two tubes from each lot. 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.

11.5 *Hydrostatic Test*—Each tube shall be subjected to the hydrostatic test, or, instead of this test, a nondestructive electric test may be used when specified by the purchaser.

12. Product Marking

12.1 In addition to the marking prescribed in Specification A 450/A 450M, the marking shall include the name and order number of the purchaser.

13. Keywords

13.1 cold drawn tube; condenser tubes; heat exchanger tubes; low carbon steel; seamless tube

EXPLANATORY NOTES

NOTE 1—For purposes of design, the following tensile properties may be assumed:

Tensile strength, min, ksi [MPa]	47 [325]
Yield strength, min, ksi [MPa]	26 [180]
Elongation in 2 in. or 50 mm, min, %	35

Designation: A 178/A 178M – 02

Standard Specification for Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes[1]

This standard is issued under the fixed designation A 178/A 178M; 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*

1.1 This specification[2] covers minimum-wall-thickness, electric-resistance-welded tubes made of carbon steel and carbon-manganese steel intended for use as boiler tubes, boiler flues, superheater flues, and safe ends.

NOTE 1—Type C and D tubes are not suitable for safe-ending for forge welding.

1.2 The tubing sizes and thicknesses usually furnished to this specification are ½ to 5 in. [12.7 to 127 mm] in outside diameter and 0.035 to 0.360 in. [0.9 to 9.1 mm], inclusive, in minimum wall thickness. Tubing having other dimensions may be furnished, provided such tubes comply with all other requirements of this specification.

1.3 Mechanical property requirements do not apply to tubing smaller than ⅛ in. [3.2 mm] in inside diameter or 0.015 in. [0.4 mm] in thickness.

1.4 Optional supplementary requirements are provided and when desired, shall be so stated in the order.

1.5 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 450/A 450M Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes[3]

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing[4]

E 273 Practice for Ultrasonic Examination of Longitudinal Welded Pipe and Tubing[4]

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 (electric-resistance-welded tubes),

3.1.3 Grade (A, C, or D, Table 1),

3.1.4 Size (outside diameter and minimum wall thickness),

3.1.5 Length (specific or random),

3.1.6 Optional requirements (product analysis, Section 7; crush test, Section 10; hydrostatic or nondestructive electric test, 11.6),

3.1.7 Test report required (Certification Section of Specification A 450/A 450M),

3.1.8 Specification designation,

3.1.9 Individual supplementary requirements, if required, and

3.1.10 Special requirements.

4. Manufacture

4.1 The steel for Grade D shall be killed.

4.2 Tubes shall be made by electric-resistance welding.

5. Heat Treatment

5.1 After welding, all tubes shall be heat treated at a temperature of 1650°F [900°C] or higher and followed by cooling in air or in the cooling chamber of a controlled-atmosphere furnace. Cold-drawn tubes shall be heat treated after the final cold-draw pass at a temperature of 1200°F [650°C] or higher.

[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 A01.09 on Carbon Steel Tubular Products.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-178 in Section II of that Code.

[3] *Annual Book of ASTM Standards*, Vol 01.01.

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

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

TABLE 1 Chemical Requirements

Element	Composition, %		
	Grade A, Low-Carbon Steel	Grade C, Medium-Carbon Steel	Grade D, Carbon-Manganese Steel
Carbon	0.06–0.18	0.35 max	0.27 max
Manganese	0.27–0.63	0.80 max	1.00–1.50
Phosphorus, max	0.035	0.035	0.030
Sulfur, max	0.035	0.035	0.015
Silicon	...	...	0.10 min

6. Chemical Composition

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

6.2 When a grade is ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed in Table 1 is not permitted.

7. Product Analysis

7.1 When requested on the purchase order, a product analysis shall be made by the manufacturer or supplier from one tube per 100 pieces for sizes over 3 in. [76.2 mm] and one tube per 250 pieces for sizes 3 in. [76.2 mm] and under; or when tubes are identified by heat, one tube per heat shall be analyzed. The chemical composition thus determined shall conform to the requirements specified.

7.2 If the original test for product analysis fails, retests of two additional 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 (Note 2) shall be rejected or, at the option of the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specifications shall be rejected.

NOTE 2—A lot consists of 250 tubes for sizes 3 in. [76.2 mm] and under and of 100 tubes for sizes over 3 in. [76.2 mm], prior to cutting to length.

8. General Requirements

8.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A 450/A 450M unless otherwise provided herein.

9. Tensile Requirements

9.1 Grade C and D tubes shall conform to the requirements as to tensile properties prescribed in Table 2.

TABLE 2 Tensile Requirements

	Grade C	Grade D
Tensile strength, min, ksi [MPa]	60 [415]	70 [485]
Yield strength, min, ksi [MPa]	37 [255]	40 [275]
Elongation in 2 in. or 50 mm, min, %	30	30
For longitudinal 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 points shall be made.	1.50[A]	1.50[A]

[A] See Table 3 for the computed minimum values.

NOTE 3—*Explanatory Note*—For purposes of design the following tensile properties may be assumed for Grade A tubes:

Tensile strength, min, ksi [MPa]	47 [325]
Yield Strength, min, ksi [MPa]	26 [180]
Elongation in 2 in. or 50 mm, min, %	35

10. Crush Test

10.1 When required by the purchaser, crushing tests shall be made on sections of tube 2½ in. [63 mm] in length which shall stand crushing longitudinally without cracking, splitting, or opening at the weld, as follows:

Wall Thickness of Tubes, in. [mm]	Height of Crushed Section, in. [mm]	
	Grade A Tubes	Grade C and D Tubes
0.135 [3.43] and under	¾ [19] or until outside folds are in contact	Crush tests not required
Over 0.135 [3.43]	1¼ [32]	...

10.2 Table 3 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 shown above, the minimum elongation value shall be determined by the following equation:

$$E = 48t + 15.00 \, [E = 1.87t + 15.00]$$

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

10.3 For tubing less than 1 in. [25.4 mm] in outside diameter, the length of the specimen shall be 2½ times the outside diameter of the tube. Slight surface checks shall not be cause for rejection.

11. Mechanical Tests Required

11.1 *Flattening Test*:

11.1.1 For Grade A, one flattening test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof, and from each 2000 ft [600 m] or fraction thereof of safe-end material.

11.1.2 For Grades C and D, one flattening test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof.

11.2 *Flange Test*:

11.2.1 For Grade A, one flange test shall be made on specimens from each of two tubes from each lot (Note 2) or

TABLE 3 Minimum Elongation Values

Wall Thickness		Elongation in 2 in. or 50 mm, min, %[A]
in.	mm	
5⁄16 (0.312)	8	30
9⁄32 (0.281)	7.2	29
¼ (0.250)	6.4	27
7⁄32 (0.219)	5.6	26
3⁄16 (0.188)	4.8	24
5⁄32 (0.156)	4	22
⅛ (0.125)	3.2	21
3⁄32 (0.094)	2.4	20
1⁄16 (0.062)	1.6	18

[A] Calculated elongation requirements shall be rounded to the nearest whole number.

fraction thereof, and from each 2000 ft [600 m] or fraction thereof of safe-end material.

11.2.2 For Grades C and D, one flange test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof. The width of the flange shall not be less than 75 % of that specified in Specification A 450/A 450M.

11.3 *Crush Test*—For Grade A, when required by the purchaser, one crush test shall be made on specimens from each of two tubes from each lot (Note 2) or fraction thereof, and from each 2000 ft [600 m] or fraction thereof of safe-end material.

11.4 *Tension Test*—For Grades C and D, one tension test shall be made on specimens from each of two tubes from each lot. The term *lot* for tension test requirements 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.

11.5 *Reverse Flattening Test*—One reverse flattening test shall be made on each 1500 ft [450 m] of finished tubing.

11.6 *Hydrostatic or Nondestructive Electric Test*—Each tube shall be subjected to either the hydrostatic or the nondestructive electric test. The purchaser may specify which test is to be used.

12. Forming Operations

12.1 When inserted in the boiler, tubes shall withstand expanding and beading without showing cracks or flaws, or opening at the weld. When properly manipulated, superheater tubes shall withstand all forging, welding, and bending operations necessary for application without developing defects.

13. Product Marking

13.1 In addition to the marking prescribed in Specification A 450/A 450M, the letters “ERW” shall be legibly stenciled on each tube, or marked on a tag attached to the bundle or box in which the tubes are shipped.

13.2 The manufacturer’s name or symbol may be placed permanently on each tube by rolling or light stamping before normalizing. If a single stamp is placed on the tube by hand, this mark should not be less than 8 in. [200 mm] from one end of the tube.

14. Keywords

14.1 boiler tube; resistance welded steel tube; steel tube, carbon; welded steel tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and production order or contract. These requirements shall not be considered, unless specified in the order and the necessary tests shall be made at the mill.

S1. Additional Testing of Welded Tubing for ASME Requirements

S1.1 The weld seam of each tube shall be subjected to an ultrasonic inspection employing Practices E 273 or E 213 with the rejection criteria referenced in Specification A 450/A 450M.

S1.2 If Practice E 273 is employed, a 100 % volumetric inspection of the entire length of each tube shall also be performed using one of the nondestructive electric tests permitted by Specification A 450/A 450M.

S1.3 The test methods described in the supplement may not be capable of inspecting the end portions of tubes. This condition is referred to as end effect. This portion, as determined by the manufacturer, shall be removed and discarded.

S1.4 In addition to the marking prescribed in Specification A 450/A 450M, “S1” shall be added after the grade designation.

SUMMARY OF CHANGES

This section identifies the location of selected changes to this specification that have been incorporated since the last edition, A 178/A 178M-95 (2002), as follows:

(1) Paragraph 1.4 was deleted and the subsequent subsections were renumbered.
(2) Paragraph 2.1 was revised to delete the reference to Specification A 520.
(3) Specification A 226/A 226M was deleted from Section 2.

Designation: A 139/A 139M – 04

Standard Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over)[1]

This standard is issued under the fixed designation A 139/A 139M; 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*

1.1 This specification covers five grades of electric-fusion (arc)-welded straight-seam or helical-seam steel pipe. Pipe of NPS 4 (Note 1) and larger with nominal (average) wall thickness of 1.0 in. [25.4 mm] and less are covered. Listing of standardized dimensions are for reference (Note 2). The grades of steel are pipe mill grades having mechanical properties which differ from standard plate grades. The pipe is intended for conveying liquid, gas, or vapor.

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."

NOTE 2—A comprehensive listing of standardized pipe dimensions is contained in ASME B36.10M[2].

NOTE 3—The suitability of pipe for various purposes is somewhat dependent on its dimensions, properties, and conditions of service. For example, for high-temperature service see applicable codes and Specification A 691.

1.2 The values stated in either inch-pound units or in SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values in each system are not exact equivalents; therefore, each system is to be used independently of the other.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 691 Specification for Carbon and Alloy Steel Pipe, Electric Fusion-Welded for High-Pressure Service at High Temperatures

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E 59 Practice for Sampling Steel and Iron for Determination of Chemical Composition[4]

2.2 *American Welding Society Standard:*[5]

AWS B2.1 Standard for Welding Procedure and Performance Qualifications Welding Handbook, Vol 1, 8th ed

2.3 *ASME Standards:*[6]

ASME B36.10M Welded and Seamless Wrought Steel Pipe

ASME B36.19M Stainless Steel Pipe

ASME Boiler and Pressure Vessel Code: Section IX, Welding Qualifications

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 (electric-fusion-(arc) welded steel pipe),

3.1.3 Grade (Table 1),

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

3.1.5 Lengths (specific or random, Section 17),

3.1.6 End finish (Section 18),

3.1.7 Hydrostatic test pressure (Section 16, Note 8, and Note 9),

3.1.8 ASTM specification designation, and

3.1.9 End use of material.

4. Process

4.1 The steel shall be made by one or more of the following processes: open-hearth, basic-oxygen, or electric-furnace.

4.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

NOTE 4—The term "basic-oxygen steelmaking" is used generically to

[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 A01.09 on Carbon Steel Tubular Products.

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[2] *Annual Book of ASTM Standards*, Vol 01.01.

[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] Withdrawn.

[5] Available from American Welding Society, 550 NW LeJeune Rd., Miami, FL 33135.

[6] Available from American Society of Mechanical Engineers, Three Park Ave., New York, NY 10016-5990.

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

TABLE 1 Chemical Requirements

Element	Composition, max, %				
	Grade A	Grade B	Grade C	Grade D	Grade E
Carbon	0.25	0.26	0.28	0.30	0.30
Manganese	1.00	1.00	1.20	1.30	1.40
Phosphorus	0.035	0.035	0.035	0.035	0.035
Sulfur	0.035	0.035	0.035	0.035	0.035

describe processes in which molten iron is refined to steel under a basic slag in a cylindrical furnace lined with basic refractories, by directing a jet of high-purity gaseous oxygen onto the surface of the hot metal bath.

5. Manufacture

5.1 The longitudinal edges of the steel shall be shaped to give the most satisfactory results by the particular welding process employed. The weld shall be made by automatic (Note 5) means (except tack welds if used) and shall be of reasonably uniform width and height for the entire length of the pipe.

NOTE 5—Upon agreement between the purchaser and the manufacturer, manual welding by qualified procedure and welders may be used as an equal alternative under these specifications.

5.2 All weld seams made in manufacturing pipe shall be made using complete joint penetration groove welds.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements prescribed in Table 1 and the chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

7. Tensile Requirements for the Steel

7.1 Longitudinal tension test specimens taken from the steel shall conform to the requirements as to tensile properties prescribed in Table 2. At the manufacturer's option, the tension test specimen for sizes 8⅝ in. [219.1 mm] in outside diameter and larger may be taken transversely as described in 19.4.

7.2 The yield point shall be determined by the drop of the beam, by the halt in the gage of the testing machine, by the use of dividers, or by other approved methods. The yield strength corresponding to a permanent offset of 0.2 % of the gage length of the specimen, or to a total extension of 0.5 % of the gage length under load shall be determined.

8. Tensile Requirements of Production Welds

8.1 Reduced-section tension test specimens taken perpendicularly across the weld in the pipe, with the weld reinforcement removed, shall show a tensile strength not less than 95 %

TABLE 2 Tensile Requirements

	Grade A	Grade B	Grade C	Grade D	Grade E
Tensile strength, min, ksi [MPa]	48 [330]	60 [415]	60 [415]	60 [415]	66 [455]
Yield strength, min, ksi [MPa]	30 [205]	35 [240]	42 [290]	46 [315]	52 [360]
Elongation in 2 in. or 50 mm, min, %:					
Basic minimum elongation for walls 5⁄16 in. [7.9 mm] and over in thickness, longitudinal strip tests	35	30	25	23	22
For longitudinal strips tests, a deduction for each 1⁄32-in. [0.8-mm] decrease in wall thickness below 5⁄16 in. [7.9 mm] from the basic minimum elongation of the following percentage[A]	1.75[A]	1.50[A]	1.25	1.50	2.0
Elongation in 8 in. or 200 mm, min, %[B,C]	Inch Pound Units, *1500/specified minimum tensile strength (ksi)* SI Units, *10 300/specified minimum tensile strength [MPa]*				

[A] The table below gives the computed minimum values.
[B] For wall thicknesses ½ in. [12.7 mm] and greater, the elongation may be taken in 8 in. or 200 mm.
[C] The elongation in 8 in. or 200 mm need not exceed 30 %.

Wall Thickness		Elongation in 2 in. or 50 mm, min, %	
in.	mm	Grade A	Grade B
5⁄16 (0.312)	7.9	35.00	30.00
9⁄32 (0.281)	7.1	33.25	28.50
1⁄4 (0.250)	6.4	31.50	27.00
7⁄32 (0.219)	5.6	29.75	25.50
3⁄16 (0.188)	4.8	28.00	24.00
5⁄32 (0.156)	4.0	26.25	22.50
1⁄8 (0.125)	3.7	24.50	21.00
3⁄32 (0.094)	2.4	22.75	19.50
1⁄16 (0.062)	1.6	21.00	18.00

NOTE—The above table 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 shown above, the minimum elongation value shall be determined by the following equation:

Grade	Equation Inch-Pound Units	Equation SI Units
A	$E = 56t + 17.50$	$E = 2.20t + 17.50$
B	$E = 48t + 15.00$	$E = 1.89t + 15.00$
C	$E = 40t + 12.50$	$E = 1.57t + 12.50$
D	$E = 48t + 8$	$E = 1.89t + 8$
E	$E = 64t + 2$	$E = 2.52t + 2$

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

of the minimum specified in Section 7. At the manufacturer's option, the test may be made without removing the weld reinforcement, in which case the tensile strength shall be not less than that specified in Section 7.

9. Heat Analysis

9.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 6. This analysis shall be made from a test ingot taken during the pouring of the heat. When requested by the purchaser, the chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 6.

10. Product Analysis

10.1 An analysis may be made by the purchaser on samples of pipe selected at random and shall conform to the requirements specified in Section 6. Samples for chemical analysis, except for spectrochemical analysis, shall be taken in accordance with Method E 59. The number of samples shall be determined as follows:

NPS	Number of Samples Selected
Under 14	2 for each lot of 200 pipes or fraction thereof
14 to 36, incl	2 for each lot of 100 pipes or fraction thereof
Over 36	2 for each 3000 ft or fraction thereof

10.2 *Retests*—If the analysis of either length of pipe or length of skelp does not conform to the requirements specified in Section 6, analyses of two additional lengths from the same lot shall be made, each of which shall conform to the requirements specified.

11. Dimensions, Mass, and Permissible Variations

11.1 *Mass*—The specified mass per unit length shall be calculated using the following equation:

$$M = C(D - t)t \quad (1)$$

where:
C = 10.69 [0.02466],
M = mass per unit length, lb/ft [kg/m],
D = outside diameter, in. [mm], specified or calculated (from inside diameter and wall thickness), and
t = specified wall thickness, in. (to 3 decimal places) [mm] (to 2 decimal places)

NOTE 6—The mass per unit length given in ASME B36.10M and ASME B36.19M and the calculated mass given by the equation of 11.1 are for carbon steel pipe. The mass per unit length of pipe made of ferritic stainless steels may be about 5 % less, and that made of austenitic stainless steel about 2 % greater than the values given. The specified mass of an individual pipe length shall be calculated as its specified mass per unit length times its length.

11.1.1 The mass of any length of pipe shall not vary more than 10 % over its specified mass.

11.1.2 The mass of any length of pipe shall not vary more than 5 % under the specified mass if the specified wall thickness is 0.188 in. [4.78 mm] or less or more than 5.5 % under if the specified wall thickness is greater than 0.188 in. [4.78 mm].

11.1.3 The mass of a carload lot shall not vary more than 1.75 % under the specified mass. A carload lot is considered to be a minimum of 40 000 lb [18 Mg] shipped on a conveyance.

11.2 *Thickness*—The minimum wall thickness at any point shall be not more than 12.5 % under the nominal wall thickness specified.

11.3 *Circumference*—The pipe shall be substantially round. The outside circumference of the pipe shall not vary more than ±1.0 %, but not exceeding ±¾ in. [19.0 mm], from the nominal outside circumference based upon the diameter specified, except that the circumference at ends shall be sized, if necessary, to meet the requirements of Section 18.

11.4 *Straightness*—Finished pipe shall be commercially straight. When specific straightness requirements are desired, the order should so state, and the tolerance shall be a matter of agreement between the purchaser and the manufacturer.

11.5 *Ovality (Out-of-Roundness)*—The pipe diameter, within 4.0 in. [100 mm] of ends, shall not vary more than 1 % from the specified diameter as measured across any single plane with a bar gage, caliper, or other instrument capable of measuring actual diameter.

12. Finish

12.1 *Repair by Welding*—The manual, or automatic arc, welding of injurious defects in the pipe wall, provided their depth does not exceed one third the specified wall thickness, will be permitted. Defects in the welds, such as sweats or leaks, shall be repaired or the piece rejected at the option of the manufacturer. Repairs of this nature shall be made by completely removing the defect, cleaning the cavity, and then welding.

12.2 All repaired pipe shall be tested hydrostatically in accordance with Section 16.

13. Retests

13.1 If any specimen tested under Sections 8 or 15 fails to meet the requirements, retests of two additional specimens from the same lot of pipe shall be made, all of which shall meet the specified requirements. If any of the retests fail to conform to the requirements, test specimens may be taken from each untested pipe length, at the manufacturer's option, and each specimen shall meet the requirements specified, or that pipe shall be rejected.

14. Number of Production Test Specimens

14.1 One longitudinal tension test specimen specified in 19.2 shall be made from the steel of each heat, or fraction thereof, used in the manufacture of the pipe.

14.2 One reduced-section production weld test specimen specified in 19.5 shall be taken from a length of pipe from each lot of 3000 ft (914 m) of pipe, or fraction thereof, of each size and wall thickness.

14.3 If any test specimen shows defective machining or develops flaws not associated with the quality of the steel or the welding, it may be discarded and another specimen substituted.

14.4 Each length of pipe shall be subjected to the hydrostatic test specified in Section 16.

15. Qualification of Welding Procedure

15.1 Welding procedures shall be qualified in accordance with the requirements of AWS B2.1; ASME Boiler and

Pressure Vessel Code, Section IX; or other qualification procedures as noted in the American Welding Society Welding Handbook. Tests and test values shall be as specified in 15.2 and 15.3.

15.2 Two reduced-section tension specimens made in accordance with Fig. 1, with the weld reinforcement removed, shall show a tensile strength not less than 100 % of the minimum specified tensile strength of the grade of steel used.

15.3 Bend test specimens (two face-bend and two root-bend or four side-bend as designated by the welding procedure according to thickness) shall be prepared in accordance with Fig. 2 and shall withstand being bent 180° in a jig substantially in accordance with Fig. 3. The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. [3.2 mm] in any direction are present in the weld metal or between the weld and the pipe metal after bending. Cracks that originate along the edges of the specimens during testing, and that are less than ¼ in. [6.4 mm] in any direction shall not be considered. (If necessary, the specimen shall be broken apart to permit examination of the fracture.)

16. Hydrostatic Test (Note 7)

16.1 Each length of pipe shall be tested by the manufacturer to a hydrostatic pressure that will produce in the pipe wall a stress of not less than 60 % of the specified minimum yield strength at room temperature. The pressure shall be determined by the following equation:

$$P = 2St/D \tag{2}$$

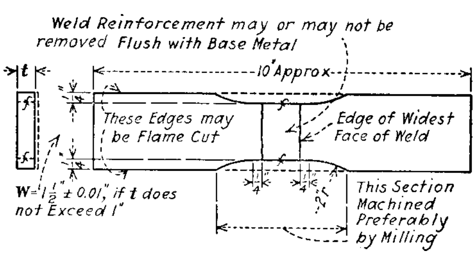
where:

P = hydrostatic test pressure, psi [MPa] (not to exceed 2800 psi [19.3 MPa] in any case) (Note 8),
S = 0.60 to 0.85 times the specified minimum yield strength of the grade of steel used in psi [MPa],
t = specified wall thickness, in. [mm], and
D = specified outside diameter, in.[mm]

NOTE 7—A hydrostatic sizing operation is not to be considered a hydrostatic test or a substitute for it.

NOTE 8—When the diameter and wall thickness of pipe are such that the capacity limits of testing equipment are exceeded by these requirements, the test pressures may be reduced by agreement between the purchaser and the manufacturer.

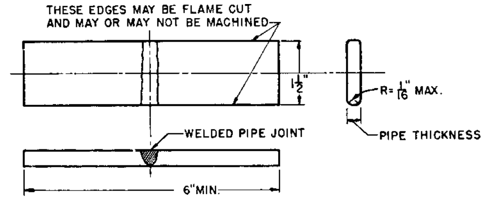
NOTE 9—Where specified in the purchase order, the pipe may be tested: (1) to 1.5 times the specified working pressure, provided the test pressure does not exceed 2800 psi [19.3 MPa] or produce a fiber stress in excess of 85 % of the specified minimum yield strength for the applicable pipe grade, or (2) to a fiber stress of 85 % or less of the specified minimum yield strength for the applicable pipe grade, provided that the test pressure does not exceed 2800 psi [19.3 MPa].



Metric Equivalents

in.	0.01	¼	1½	10
mm	0.3	6.4	38	250

FIG. 1 Reduced-Section Tension Test Specimen



Metric Equivalents

in.	1⁄16	1½	6
mm	1.6	38	150

NOTE 1—Weld reinforcement may or may not be removed flush with the surface of the specimen.

NOTE 2—Shown in Fig. 2 is a root- or face-bend specimen. Side-bend specimens shall have a thickness (T) of ⅜ in. (9.5 mm) and a width equal to the pipe wall thickness.

FIG. 2 Guided-Bend Test Specimen

16.2 Test pressure shall be held for not less than 5 s, or for a longer time as agreed upon between the purchaser and the manufacturer.

17. Lengths

17.1 Pipe lengths shall be supplied in accordance with the following regular practice:

17.1.1 Specific lengths shall be as specified on the order with a tolerance of ±½ in. [12.7 mm], except that the shorter lengths from which test coupons have been cut shall also be shipped.

17.1.2 Unless otherwise specified random lengths shall be furnished in lengths averaging 29 ft [8.9 m] or over, with a minimum length of 20 ft [6.1 m], but not more than 5 % may be under 25 ft [7.6 m].

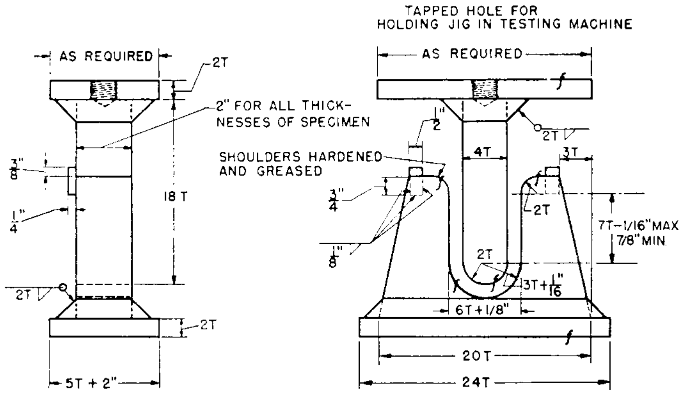
17.1.3 Pipe lengths containing circumferentially welded joints (Note 6) shall be permitted by agreement between the purchaser and the manufacturer. Tests of these welded joints shall be made in accordance with the production weld tests described in Section 8. The number of production weld tests shall be one for each lot of 100 joints or fraction thereof, but not less than one for each welder or welding operator.

NOTE 10—Circumferentially welded joints are defined for the purpose of these specifications as a welded seam lying in one plane, used to join lengths of straight pipe.

18. Ends

18.1 Pipe shall be furnished with plain right-angle cut or beveled ends as specified. All burrs at the ends of pipe shall be removed.

18.2 When pipe is specified to have the ends prepared for field welding of circumferential joints, the ends shall be beveled on the outside to an angle of 35°, measured from a line drawn perpendicular to the axis of the pipe, with a tolerance of ±2½ ° and with a width of root face (or flat at the end of the pipe) of 1⁄16 ± 1⁄32 in. [1.6 ± 0.8 mm]. Unless otherwise specified, the outside circumference of pipe ends for a distance of not less than 4 in. [101.6 mm] shall not vary more than



Metric Equivalents

in.	1⁄16	1⁄8	1⁄4	3⁄8	1⁄2	3⁄4	7⁄8	2
mm	1.6	3.2	6.4	9.5	12.7	19.0	22.2	50.8

FIG. 3 Jig for Guided-Bend Test

±60 % of the nominal wall thickness of the pipe from the nominal outside circumference based on the diameter specified, except that the tolerance shall be not less than ±3⁄16 in. [4.8 mm].

18.3 Pipe ends for use with mechanical couplings shall have tolerances within the limits required by the manufacturer of the type of coupling to be used.

18.4 Upon agreement between the purchaser and the manufacturer, the ends of the pipe may be sized within agreed-upon tolerances, if necessary to meet the requirements of special installations.

19. Production Test Specimens and Methods of Testing

19.1 The test specimens and the tests required by these specifications shall conform to those described in Test Methods and Definitions A 370.

19.2 The longitudinal tension tests specimen of the steel shall be taken from the end of the pipe in accordance with Fig. 4, or by agreement between the purchaser and the manufacturer, or may be taken from the skelp or plate, at a point which will be approximately 90° of arc from the weld in the finished pipe.

19.3 If the tension test specimen is taken transversely, the specimen shall be taken in accordance with Fig. 5.

19.4 The specimens for the reduced-section tension test of production welds shall be taken perpendicularly across the weld at the end of the pipe. The test specimens shall have the weld approximately in the middle of the specimen. The specimens shall be straightened and tested at room temperature.

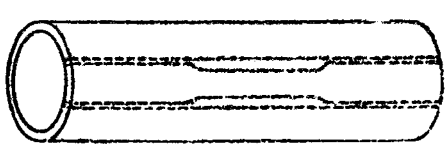


FIG. 4 Location from Which Longitudinal Tension Test Specimens Are To Be Cut from Large Diameter Tubing

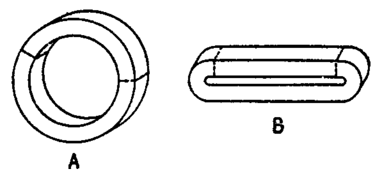


FIG. 5 Location of Transverse Tension Test Specimen in Ring Cut from Tubular Steel Products

19.5 Reduced-section tension test specimens shall be prepared in accordance with Fig. 1.

20. Inspection

20.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment and, unless otherwise specified, shall be so conducted as not to interfere unnecessarily with the operation of the works. If agreed upon, the manufacturer shall notify the purchaser in time so that he may have his inspector present to witness any part of the manufacture or tests that may be desired.

20.2 *Certification*—Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the chemical and tensile tests shall be furnished.

21. Rejection

21.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

21.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

22. Protective Coating

22.1 If agreed upon between the purchaser and the manufacturer, the pipe shall be given a protective coating of the kind and in the manner specified by the purchaser.

23. Product Marking

23.1 Each section of pipe shall be marked with the manufacturer's distinguishing marking, the specification number, the grade of pipe, and other marking if required and agreed upon between the purchaser and the manufacturer.

23.2 *Bar Coding*—In addition to the requirements in 23.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

24. Keywords

24.1 arc welded steel pipe; fusion welded steel pipe; steel pipe; welded steel pipe

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 139 – 00, that may impact the use of this specification. (Approved March 1, 2004)

(*1*) Revised Sections 1, 3, 7, 11, 16, 17, and 18, Table 2, and Figures 1 and 2 to include rationalized SI units, creating a combined standard.

Designation: A 135/A 135M – 06

INTERNATIONAL

Standard Specification for Electric-Resistance-Welded Steel Pipe[1]

This standard is issued under the fixed designation A 135/A 135M; 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*

1.1 This specification[2] covers two grades of electric-resistance-welded steel pipe in NPS 2 to NPS 30 [DN 50 to DN 750] inclusive, with nominal (average) wall thickness up to 0.500 in. [12.70 mm], inclusive, and in nominal sizes NPS ¾ to NPS 5 [DN 20 to DN 125] inclusive with nominal (average) wall thickness 0.083 in. [2.11 mm] to 0.134 in. [3.40 mm], depending on size. Pipe having other dimensions (Note 1) may be furnished provided such pipe complies with all other requirements of this specification. The pipe is intended for conveying gas, vapor, water or other liquid; only Grade A is adapted for flanging and bending (Note 2). The suitability of pipe for various purposes is somewhat dependent upon its dimensions, properties, and conditions of service, so that the purpose for which the pipe is intended should be stated in the order. The pipe may be furnished either nonexpanded or cold expanded at the option of the manufacturer. When pipe is cold expanded, the amount of expansion shall not exceed 1.5 % of the outside diameter pipe size.

NOTE 1—A comprehensive listing of standardized pipe dimensions is contained in ASME B36.10M.

NOTE 2—This provision is not intended to prohibit the cold bending of Grade B pipe.

1.2 The values stated in either SI or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system is to be used independently of the other.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 865 Specification for Threaded Couplings, Steel, Black or Zinc-Coated (Galvanized) Welded or Seamless, for Use in Steel Pipe Joints

A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

E 6 Terminology Relating to Methods of Mechanical Testing

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing

E 273 Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing

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

E 1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition

2.2 *ASME Standard:*

B1.20.1 Pipe Threads, General Purpose[4]

B36.10M Welded and Seamless Wrought Steel Pipe[4,5]

2.3 *Federal Standards:*

Fed. STD No. 123 Marking for Shipments (Civil Agencies)[6]

Fed. STD No. 183 Continuous Identification Marking of Iron and Steel Products[6]

2.4 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[7]

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage[7]

3. Terminology

3.1 For definitions of terms relating to steel manufacturing and properties, refer to Terminology A 941.

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved March 1, 2006. Published April 2006. Originally approved in 1931. Last previous edition approved in 2005 as A 135 – 05.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-135 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 National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

[6] Available from General Service Administration, Washington, DC 20405.

[7] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111–5094. Attn.: NOPD.

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

3.2 For definitions of terms relating to mechanical testing, refer to Terminology E 6.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *burr*, *n*—a rough or sharp edge left on pipe ends by cutting or sawing.

3.3.2 *lot*, *n*—all pipe of the same size, wall thickness and rolled length that is produced from the same heat of steel and subject to the same heat treatment.

3.3.3 *black thread*, *n*—a thread crease exhibiting the original pipe surface after machining.

4. Ordering Information

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

4.1.1 Quantity (feet, metres, or number of lengths),

4.1.2 Name of product (electric-resistance-welded pipe),

4.1.3 Specification designation and year of issue,

4.1.4 Grade (see Table 1),

4.1.5 Size (nominal size, NPS [DN], or outside diameter; and nominal wall thickness),

4.1.6 Length (specific or random, see 12.4),

4.1.7 End finish (plain or threaded, see 13.2),

4.1.7.1 Threaded and coupled, if specified,

4.1.7.2 Threads only, if specified,

4.1.7.3 Plain end, if specified,

4.1.8 Alternative electric test (see Section 11),

4.1.9 Tension test specimen (see Section 15),

4.1.10 Heat analysis, if required (see 6.1),

4.1.11 Certificate of compliance, if required (see Section 19), and

4.1.12 Special requirements.

5. Manufacture

5.1 The steel shall be made by either or both of the following processes: basic-oxygen or electric-furnace.

5.2 Steel may be cast in ingots or may be strand cast. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

5.3 The pipe shall be manufactured from flat rolled steel in individual lengths or in continuous length by electric-resistance or electric-induction welding without the addition of extraneous material.

5.4 The weld seam of electric-resistance welded pipe to Grade B pipe shall be heat treated after welding to a minimum temperature of 1000 °F [540 °C] or processed in such a manner that no untempered martensite remains.

6. Chemical Composition

6.1 The steel shall conform to the requirements prescribed in Table 2, based on the heat analysis. When specified in the order, the heat analyses shall be reported to the purchaser or a representative of the purchaser.

7. Product Analysis

7.1 An analysis may be made by the purchaser on samples of pipe selected at random and shall conform to the requirements specified in Table 2. Methods and Practices relating to chemical analysis shall be in accordance with Test Method, Practices, and Terminology A 751.

8. Mechanical Properties Requirements

8.1 *Tensile Properties*:

TABLE 1 Tensile Requirements

	Grade A	Grade B
Tensile strength, min, ksi [MPa]	48 [330]	60 [415]
Yield strength, min, ksi [MPa]	30 [205]	35 [240]
Elongation in 2 in. or [50 mm], min, %:		
For pipe having a specified wall thickness of 5⁄16 in. [7.9 mm] or more, if tested using a longitudinal strip test specimen.	35	30
For pipe having a specified wall thickness of less than 5⁄16 in. [7.9 mm], if tested using a longitudinal strip test specimen.	A	B
For pipe of any size, if tested using a full-size longitudinal test specimen.	35	30

A The minimum elongation shall be determined by the following equation, with the calculated value rounded to the nearest percent:

$$E = 56t + 16.5$$

$$[E = 2.2t + 16.5]$$

where:

E = elongation in 2 in. or [50 mm], minimum, %, and
t = specified wall thickness, in. [mm].

B The minimum elongation shall be determined by the following equation, with the calculated value rounded to the nearest percent:

$$E = 48t + 14$$

$$[E = 1.9t + 14]$$

where:

E = elongation in 2 in. or [50 mm], minimum, %, and
t = specified wall thickness, in. [mm].

TABLE 2 Chemical Requirements

Element	Composition, max, %	
	Grade A	Grade B
Carbon	0.25	0.30
Manganese	0.95	1.20
Phosphorus	0.035	0.035
Sulfur	0.035	0.035

8.1.1 The material shall conform to the requirements as to tensile properties prescribed in Table 1.

8.1.2 The yield strength shall be determined by the offset method utilizing 0.2 % of the gage length or by the total extension under load method using 0.5 % of the gage length.

8.1.3 Longitudinal test specimens shall be full-size longitudinal test specimens (see Figure A2.1 of Test Methods and Definitions A 370) or longitudinal strip test specimens (see Specimen No. 4 in Fig. A2.3 of Test Methods and Definitions A 370).

8.2 The test specimen taken across the weld shall show a tensile strength not less than the minimum tensile strength specified for the grade of pipe ordered. This test will not be required for pipe under NPS 8 [DN 200].

9. Flattening Test

9.1 A specimen at least 4 in. [100 mm] in length shall be flattened cold between parallel plates in three steps with the weld located either 0° or 90° from the line of direction of force as required in 9.2. During the first step, which is a test for ductility of the weld, no cracks or breaks on the inside or outside surfaces shall occur before the distance between the plates is less than two thirds of the original outside diameter of the pipe. As a second step, the flattening shall be continued. During the second step, which is a test for ductility exclusive of the weld, no cracks or breaks on the inside or outside surfaces shall occur before the distance between the plates is less than one third of the original outside diameter of the pipe but is not less than five times the wall thickness of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the specimen breaks or the opposite walls of the pipe meet. Evidence of laminated or unsound material or of incomplete weld that is revealed during the entire flattening test shall be cause for rejection.

9.2 For pipe produced in single lengths, the flattening test specified in 9.1 shall be made on both crop ends cut from each length of pipe. The tests from each end shall be made alternately with the weld at 0° and at 90° from the line of direction of force. For pipe produced in multiple lengths, the flattening test shall be made on crop ends representing the front and back of each coil with the weld at 90° from the line of direction of force, and on two intermediate rings representing each coil with the weld 0° from the line of direction of force.

9.3 Surface imperfections in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements in Section 13.

9.4 Superficial cracks as a result of surface imperfections shall not be cause for rejection.

10. Hydrostatic Test

10.1 Except as provided for in 10.3, each length of pipe shall be hydrostatically tested at the mill, without leakage through the wall, to a pressure calculated from the following equation:

$$P = 2St/D$$

where:

P = minimum hydrostatic test pressure, psi, [kPa]. The test pressure need not exceed 2500 psi [1700 kPa],
S = allowable fiber stress 18 000 psi [124 000 kPa] for Grade A and 21 000 psi [144 000 kPa] for Grade B. This does not prohibit testing at higher pressure at the manufacturer's option,
t = specified wall thickness, in. [mm], and
D = specified outside diameter, in. [mm].

Plain end pipe may be tested at the discretion of the manufacturer in single lengths or in multiple lengths.

10.2 The hydrostatic pressure shall be maintained for not less than 5 s.

10.3 When specified in the order, pipe may be furnished without hydrostatic testing, and each length so furnished shall include with the mandatory marking the letters "NH."

NOTE 3—This provision is not intended to apply to light wall (Schedule 10) pipe listed in Table X1.1.

10.4 When certification is required by the purchaser and the hydrostatic test has been omitted, the certification shall clearly state "Not Hydrostatically Tested." The specification number and material grade, as shown on the certification, shall be followed by the letters "NH."

11. Nondestructive Examination Requirements

11.1 As an alternate to the hydrostatic test, and when accepted by the purchaser, each pipe shall be tested with a nondestructive electric test in accordance with Practice E 213, Practice E 273, or Practice E 309. It is the intent of this test to reject pipe containing defects.

11.2 Recognized methods for meeting this test are electromagnetic (eddy current) or ultrasonic.

11.3 The following information is for the benefit of the user of this specification:

11.3.1 The ultrasonic examination referred to in this specification is intended to detect longitudinal imperfections having a reflective area similar to or larger than the reference notch. The examination may not detect circumferentially oriented imperfections of short, deep imperfections.

11.3.2 The eddy-current examination referenced in this specification has the capability of detecting significant imperfections, especially of the short, abrupt type.

11.3.3 The hydrostatic test referred to in Section 10 is a test method provided for in many product specifications. This test has the capability of finding imperfections of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. This test may not detect very tight, through-the-wall imperfections or imperfections that extend an appreciable distance into the wall without complete penetration.

11.3.4 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of imperfections that can be detected in the specific application of these examinations should discuss this with the manufacturer of the tubular product.

11.4 In order to accommodate the various types of nondestructive electric testing equipment and techniques in use, the calibration pipe shall contain, at the option of the producer, any one or more of the following discontinuities to establish a minimum sensitivity level for rejection:

11.4.1 *Drilled Hole*—A hole not larger than 0.031-in. [0.8-mm] diameter shall be drilled radially and completely through pipe wall, preferably in the weld area, care being taken to avoid distortion of the pipe while drilling.

11.4.2 *Transverse Tangential Notch*—A notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe preferably in the weld area. Said notch shall have a depth not exceeding 12.5 % of the nominal wall thickness of the pipe or 0.004 in., [0.10 mm], whichever is greater.

11.4.3 *Longitudinal Notch*—A notch 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the pipe axis on the outside surface of the pipe preferably in the weld area, to have a depth not exceeding 12.5 % of the nominal wall thickness of the pipe or 0.004 in. [0.10 mm], whichever is greater.

11.5 Pipe producing a signal equal to or greater than the calibration imperfection shall be rejected.

12. Dimensions, Weight (Mass), and Permissible Variations

12.1 *Weight (Mass)*—The weight (mass) of any length of pipe other than Schedule 10 shall not vary more than 3.5 % under or 10 % over that specified, but the carload weight (mass) shall be not more than 1.75 % under the nominal weight (mass). The weight (mass) of pipe furnished to Schedule 10 shall not vary more than ±10 % from that calculated using the weight (mass) per unit length prescribed in Appendix Table X1.1. The weight (mass) of the pipe shall be calculated from the relevant equation in ASME B36.10M.

NOTE 4—A system of standard pipe sizes has been approved by the American National Standards Institute as American National Standard for Welded and Seamless Wrought Steel Pipe (ASME B36.10M).

12.2 *Diameter*—The outside diameter shall not vary more than ±1 % from the nominal size specified.

12.3 *Minimum Wall Thickness*—The minimum wall thickness at any point shall be not more than 12.5 % under the specified wall thickness.

NOTE 5—The minimum wall thickness on inspection is shown in Table X1.2 of the Appendix.

12.4 *Lengths*:

12.4.1 Except as allowed in 12.4.2, pipe shall be furnished in lengths averaging 38 ft [11.6 m] or over, with a minimum length of 20 ft [6.1 m], but no more than 5 % may be under 32 ft [9.8 m]. Jointers made by welding are permissible. When threaded pipe is ordered, jointers shall be made by threaded connections and shall not exceed 5 % of the order.

12.4.2 Unless otherwise specified, Schedule 10 pipe shall be between 16 and 22 ft [4.9 and 6.7 m] for a minimum of 90 % of the footage furnished, with any balance being shorter lengths at least 8 ft [2.4 m] long.

13. Workmanship, Finish, and Appearance

13.1 The finished pipe shall be reasonably straight and free of defects. Surface inperfections in excess of 12.5 % of the nominal wall thickness shall be considered defects.

13.2 *End Finish*:

13.2.1 *Schedule 10 Pipe*—Pipe furnished to Schedule 10 shall be plain end only. All inside and outside cutting burrs shall be removed. This generally involves breaking the corners.

13.2.2 *Ends, Plain End Pipe*—Unless otherwise specified, plain end pipe for use with the Dresser or Dayton type coupling shall be reamed both outside and inside sufficiently to remove all burrs. Plain end pipe for welding shall be beveled on the outside to an angle of 30° with a tolerance of + 5° and – 0° and with a width of flat at the end of the pipe of 1⁄16 ± 1⁄32 in. [1.6 ± 0.8 mm]. When material is ordered beveled to any other than a 30° angle, it should be understood that the angle is to be measured from a line drawn perpendicular to the axis of the pipe. This means that a greater amount of material is removed with a 60° angle than with a 30° angle. Pipe shall be sufficiently free from indentations, projections, or roll marks for a distance of 8 in. [200 mm] from the end of the pipe to make a tight joint with the rubber gasket type of coupling. All plain end pipe intended for Dresser or Dayton type joints or for welding, sizes NPS 10 [DN 250] and smaller in outside diameter specified, shall be not more than 1⁄32 in. [0.8 mm] smaller than the outside diameter specified for a distance of 8 in. [200 mm] from the ends of the pipe and shall permit the passing for a distance of 8 in. [200 mm] of a ring gage that has a bore 1⁄16 in. [1.6 mm] larger than the outside diameter specified of the pipe. Sizes larger than NPS 10 [DN 250] shall be not more than 1⁄32 in. [0.8 mm] smaller than the nominal outside diameter for a distance of 8 in. [200 mm] from the end of the pipe and shall permit the passing for a distance of 8 in. [200 mm] of a ring gage which has a bore 3⁄32 in. [2.4 mm] larger than the nominal outside diameter of the pipe.

13.2.3 *Ends, Threaded Pipe*—Each end of threaded pipe shall be reamed to remove all burrs. All threads shall be in accordance with the American National Standard Pipe Threads (Note 6) and cut so as to make a tight joint when the pipe is tested at the mill to the specified internal hydrostatic pressure. The variation from the standard, when tested with the standard working gage, shall not exceed one and one-half turns either way. Pipe shall not be rounded by hammering in order to get a full thread. There shall be not more than two black threads for 3⁄4-in. [19.0-mm] taper among the perfect threads. Black threads should not be confused with imperfect threads, such as those torn, shaven, or broken.

NOTE 6—A complete description of the American National Standard Pipe Threads applicable to pipe, valves, and fittings is contained in ASME B1.20.1; also" Screw-Thread Standards for Federal Services, 1942," National Bureau of Standards *Handbook H 28*, January, 1942, the pertinent data in both sources being identical.

13.3 *Couplings*—Each length of threaded pipe shall be provided with one coupling manufactured in accordance with

Specification A 865 except that the coupling may be wrought iron (Note 7). Threads shall be cut so as to make a tight joint. Taper-tapped couplings shall be furnished on all weights (masses) of threaded pipe NPS 2½ [DN 65] and larger.

NOTE 7—For sizes NPS 2 [DN 50] and smaller, it is commercial practice to furnish straight-tapped couplings for standard-weight (mass) (Schedule 40) pipe and taper-tapped couplings for extra-strong (Schedule 80) and double-extra-strong pipe. If taper-tapped couplings are required for sizes NPS 2 [DN 50] and smaller on standard weight (mass) (Schedule 40) pipe, line pipe in accordance with Specification 5L of the American Petroleum Institute should be ordered, thread lengths to be in accordance with ASME B1.20.1. Taper-tapped couplings for sizes NPS 2 [DN 50] and smaller in standard weight (mass) may be used on mill-threaded standard weight (mass) type of the same size.

13.4 *Protective Coating*:

13.4.1 After the pipe has been subjected to the hydrostatic test, and if required by the purchaser, it shall be thoroughly cleaned of all dirt, oil, grease, loose scale, and rust; then dried, and given a protective coating of the kind and in the manner specified by the purchaser. Pipe furnished to Schedule 10 shall be normally shipped with a light coating of processing oil. If so specified, the pipe can be given a mill coating or a special coating.

14. Weld Repair

14.1 *Welding Repair*—

14.2 Defects in the pipe wall, provided their depth does not exceed one third the specified wall thickness, shall be repaired by electric welding. Defects in the welds such as sweats or leaks, unless otherwise specified, shall be repaired or the piece rejected at the option of the manufacturer. Repairs of this nature shall be made by completely removing the defect, cleaning the cavity, and then electric welding.

14.3 All repaired pipe shall be retested hydrostatically in accordance with Section 10.

15. Sampling

15.1 *Chemical Analysis*:

15.1.1 Samples for chemical analysis, except for spectrochemical analysis, shall be taken in accordance with Practice E 1806. The number of samples shall be determined as follows:

NPS	Numbers of Samples Selected
Under 6 [DN 150]	2 from each lot of 400 pipes or fraction thereof
6 [DN 150] to 20 [DN 500], incl	2 from each lot of 200 pipes or fraction thereof
Over 20 [DN 500] to 30 [DN 750], incl	2 from each lot of 100 pipes or fraction thereof

15.2 *Tension Test*:

15.2.1 One longitudinal tension test shall be made on one length (Note 8) from each lot of 400 lengths or fraction thereof of each size under NPS 8 [DN 200] and one transverse body and one transverse weld tension test on one length from each lot of 200 lengths or fraction thereof of each size NPS 8 to NPS 20 [DN 200 to DN 500] and on one length from each lot of 100 lengths or fraction thereof of each size over NPS 20 to NPS 30 [DN 500 to DN 750]. When taken from the skelp, the number of tests shall be determined in the same manner as when taken from the finished pipe.

NOTE 8—Length is defined as the length as ordered, except that in the case of orders for cut lengths shorter than double random, which is defined as the length as rolled, prior to cutting to the required short lengths.

15.3 *Flattening Test*:

15.3.1 When pipe is produced in single length, the flattening test specified in 9.1 shall be made on both crop ends cut from each length of pipe. When pipe is produced in multiple lengths, flattening tests are required on the crop ends from the front and back ends of each coil and on two intermediate rings representing each coil.

15.4 *Hydrostatic Test*:

15.4.1 Each length of pipe shall be subjected to the hydrostatic test specified in Section 10.

16. Test, Retest, and Resampling

16.1 *Chemical Analysis*:

16.1.1 If the results of the analysis of either length of pipe does not conform to the requirements specified in Section 7, analyses of two additional lengths from the same lot shall be made, each of which shall conform to the requirements specified.

16.2 *Tension Test*:

16.2.1 The test specimens and the tests required by this specification shall conform to those described in Test Methods and Definitions A 370, except that all specimens shall be tested at room temperature.

16.2.2 The longitudinal tension test specimen shall be taken from the end of the pipe, or by agreement between the manufacturer and the purchaser may be taken from the skelp, at a point approximately 90° from the weld, and shall not be flattened between gage marks. The sides of each specimen shall be parallel between gage marks. At the manufacturer option, the tension test may be made on full section of pipe.

16.2.3 Transverse weld test specimens shall be taken with the weld at the center of the specimen. Transverse body test specimens shall be taken opposite to the weld. All transverse test specimens shall be approximately 1½ in. [38 mm] wide in the gage length and shall represent the full wall thickness of the pipe from which the specimen was cut.

16.2.4 If any test specimen shows defective machining or develops flaws not associated with the quality of the steel or the welding, it may be discarded and another specimen substituted.

16.2.5 If the results of the tension tests of any lot do not conform to the requirements specified in 9.1, retests of two additional lengths from the same lot shall be made, each of which shall conform to the requirements specified.

16.2.6 If the percentage of elongation of any tension test specimen is less than that specified in 8.1, and any part of the fracture is more than ¾-in. [19.0-mm] from the center of the gage length as indicated by scribe scratches marked on the specimen before testing, the specimen may be discarded and another substituted.

16.3 *Flattening Test*:

16.3.1 Specimens for flattening tests shall be smooth at the ends and free from burrs.

16.3.2 If any section of the pipe fails to comply with the requirements of 9.1, for pipe produced in single lengths, other sections may be cut from the same end of the same length until satisfactory tests are obtained, except that the finished pipe shall not be shorter than 80 % of its length after the initial cropping; otherwise, the length shall be rejected. For pipe produced in multiple lengths, retests may be cut from each end of each individual length in the multiple; such tests shall be made with the weld alternately 0° and 90° from the line of direction of force.

16.4 All specimens shall be tested at room temperature.

17. Inspection

17.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except check analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the manufacturer's operation.

18. Rejection

18.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

18.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

19. Certificate of Compliance

19.1 When specified in the purchase order, the producer or supplier shall furnish to the purchaser a certificate of compliance stating that the pipe has been manufactured, sampled, tested and inspected in accordance with this specification (including the year of issue) and has been found to meet the requirements.

20. Identification of Material

20.1 Each length of pipe shall be legibly marked with appropriate symbols by stenciling, stamping, or rolling to show the manufacturer's name, the size, the specification designation, the grade, and the hydrostatic test pressure when tested, or the letters "NH" when not tested.

20.2 In addition to the requirements in 20.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

21. Packaging, Marking, and Loading for Shipment

21.1 When specified on the purchase order, packaging, marking, and loading for shipment shall be in accordance with Practices A 700.

21.2 When specified in the contract or purchase order, the material shall be preserved, packaged, and packed in accordance with MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 or Fed. Std. No. 183 if continuous marking is required for military agencies.

22. Keywords

22.1 eddy current testing; electric resistance welded pipe; hydrostatic testing; plain end pipe; Schedule 10 pipe; threaded pipe

APPENDIX

(Nonmandatory Information)

X1. ADDITIONAL DATA

X1.1 Additional data on dimensions nominal weights (masses) and test pressures is provided in Table X1.1.

X1.2 Additional data on wall thicknesses are provided in Table X1.2.

TABLE X1.1 Dimensions, Nominal Weights (Masses), and Test Pressures for Light Wall Steel Pipe

NPS	DN	Outside Diameter, in. [mm]	Schedule 10 Specified Wall Thickness[A] in. [mm]	Schedule 10 Weight (Mass) Per Unit Length lb/ft [kg/m]	Test Pressure, psi [MPa][A] Grade A	Test Pressure, psi [MPa][A] Grade B
¾	20	1.050 [26.7]	0.083 [2.11]	0.86 [1.28]	2500 [17 200]	2500 [17 200]
1	25	1.315 [33.4]	0.109 [2.77]	1.41 [2.09]	2500 [17 200]	2500 [17 200]
1¼	32	1.660 [42.2]	0.109 [2.77]	1.81 [2.69]	2400 [16 500]	2500 [17 200]
1½	40	1.900 [48.3]	0.109 [2.77]	2.09 [3.11]	2100 [14 500]	2400 [16 500]
2	50	2.375 [60.3]	0.109 [2.77]	2.64 [3.93]	1700 [11 700]	1900 [13 100]
2½	65	2.875 [73.0]	0.120 [3.05]	3.53 [5.26]	1500 [10 300]	1700 [11 700]
3	80	3.500 [88.9]	0.120 [3.05]	4.34 [6.46]	1200 [8 200]	1400 [9 600]
3½	90	4.000 [101.6]	0.120 [3.05]	4.98 [7.41]	1000 [6 900]	1200 [8 200]
4	100	4.500 [114.3]	0.120 [3.05]	5.62 [8.37]	900 [6 200]	1100 [7 600]
5	125	5.563 [141.3]	0.134 [3.40]	7.78 [11.58]	850 [5 900]	1000 [6 900]

[A] The test pressures are calculated by the following equation (but need not exceed 2500 psi or [17 200 KPa]):

$$P = 2St/D$$

where:

P = pressure, psi [kPa],
S = fiber stress 60 % of the specified minimum yield strength, psi [kPa],
t = specified wall thickness, in. [mm], and
D = specified outside diameter, in. [mm].

TABLE X1.2 Minimum Permissible Wall Thickness on Inspection

NOTE 1—The following equation, upon which this table is based, is used to derive the minimum permissible wall thickness values from the specified wall thickness values, with the calculated values rounded to three decimal places in accordance with the rounding method of Practice E 29:

$$t_m \times 0.875 = t$$

where:
t_m = minimum permissible wall thickness, in. [mm], and
t = specified wall thickness, in. [mm].

NOTE 2—This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

Specified Wall Thickness (t), in. [mm]	Minimum Permissible Wall Thickness (t_m), in. [mm]	Specified Wall Thickness (t), in. [mm]	Minimum Permissible Wall Thickness (t_m), in. [mm]	Specified Wall Thickness (t), in. [mm]	Minimum Permissible Wall Thickness (t_m), in. [mm]
0.068 [1.73]	0.060 [1.52]	0.294 [7.47]	0.257 [6.53]	0.750 [19.05]	0.656 [16.66]
0.088 [2.24]	0.077 [1.96]	0.300 [7.62]	0.262 [6.65]	0.812 [20.62]	0.710 [18.03]
0.091 [2.31]	0.080 [2.03]	0.307 [7.80]	0.269 [6.83]	0.844 [21.44]	0.738 [18.75]
0.095 [2.41]	0.083 [2.11]	0.308 [7.82]	0.270 [6.86]	0.864 [21.94]	0.756 [19.20]
0.113 [2.87]	0.099 [2.51]	0.312 [7.92]	0.273 [6.93]	0.875 [22.22]	0.766 [19.46]
0.119 [3.02]	0.104 [2.64]	0.318 [8.08]	0.278 [7.06]	0.906 [23.01]	0.793 [20.14]
0.125 [3.18]	0.109 [2.77]	0.322 [8.18]	0.282 [7.16]	0.937 [23.82]	0.820 [20.85]
0.126 [3.20]	0.110 [2.79]	0.330 [8.38]	0.289 [7.34]	0.968 [24.59]	0.847 [21.51]
0.133 [3.38]	0.116 [2.95]	0.337 [8.56]	0.295 [7.49]	1.000 [25.40]	0.875 [22.22]
0.140 [3.56]	0.122 [3.10]	0.343 [8.71]	0.300 [7.62]	1.031 [26.19]	0.902 [22.91]
0.145 [3.68]	0.127 [3.23]	0.344 [8.74]	0.301 [7.65]	1.062 [26.97]	0.929 [23.60]
0.147 [3.73]	0.129 [3.28]	0.358 [9.09]	0.313 [7.95]	1.094 [27.79]	0.957 [24.31]
0.154 [3.91]	0.135 [3.43]	0.365 [9.27]	0.319 [8.10]	1.125 [28.58]	0.984 [24.99]
0.156 [3.96]	0.136 [3.45]	0.375 [9.52]	0.328 [8.33]	1.156 [29.36]	1.012 [25.70]
0.179 [4.55]	0.157 [3.99]	0.382 [9.70]	0.334 [8.48]	1.219 [30.96]	1.066 [27.08]
0.187 [4.75]	0.164 [4.17]	0.400 [10.16]	0.350 [8.89]	1.250 [31.75]	1.094 [27.79]
0.188 [4.78]	0.164 [4.17]	0.406 [10.31]	0.355 [9.02]	1.281 [32.54]	1.121 [28.47]
0.191 [4.85]	0.167 [4.24]	0.432 [10.97]	0.378 [9.60]	1.312 [33.32]	1.148 [29.16]
0.200 [5.08]	0.175 [4.44]	0.436 [11.07]	...	1.343 [34.11]	1.175 [29.85]
0.203 [5.16]	0.178 [4.52]	0.437 [11.10]	0.382 [9.70]	1.375 [34.92]	1.203 [30.56]
0.216 [5.49]	0.189 [4.80]	0.438 [11.13]	0.383 [9.73]	1.406 [35.71]	1.230 [31.24]
0.218 [5.54]	0.191 [4.85]	0.500 [12.70]	0.438 [11.13]	1.437 [36.53]	1.258 [31.95]
0.219 [5.56]	0.192 [4.88]	0.531 [13.49]	0.465 [11.81]	1.500 [38.10]	1.312 [33.32]
0.226 [5.74]	0.198 [5.03]	0.552 [14.02]	0.483 [12.27]	1.531 [38.89]	1.340 [34.04]
0.237 [6.02]	0.207 [5.26]	0.562 [14.27]	0.492 [12.50]	1.562 [39.67]	1.367 [34.72]
0.250 [6.35]	0.219 [5.56]	0.593 [15.06]	0.520 [13.21]	1.594 [40.69]	1.394 [35.43]
0.258 [6.55]	0.226 [5.74]	0.600 [15.24]	0.525 [13.34]	1.750 [44.45]	1.531 [38.89]
0.276 [7.01]	0.242 [6.15]	0.625 [15.88]	0.547 [13.89]	1.781 [45.24]	1.558 [39.57]
0.277 [7.04]	0.242 [6.15]	0.656 [16.66]	0.574 [14.58]	1.812 [46.02]	1.586 [40.28]
0.279 [7.09]	0.244 [6.20]	...	...	...	...
0.280 [7.11]	0.245 [6.22]	0.687 [17.48]	0.602 [15.29]	2.062 [52.37]	1.804 [45.82]
0.281 [7.14]	0.246 [6.25]	0.719 [18.26]	0.629 [15.96]	2.343 [59.54]	2.050 [52.10]

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 135 – 05, that may impact the use of this specification. (Approved March 1, 2006)

(*1*) SI units have been added throughout the text and tables to create a combined standard.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 135 – 01, that may impact the use of this specification. (Approved March 1, 2005)

(*1*) Revised 11.1.

Designation: A 134 – 96 (Reapproved 2005)

Standard Specification for Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)[1]

This standard is issued under the fixed designation A 134; 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

1.1 This specification covers electric-fusion (arc)-welded straight seam or spiral seam steel pipe NPS 16 and over in diameter (inside or outside as specified by purchaser), with wall thicknesses up to ¾ in. (19.0 mm), inclusive. Pipe having other dimensions may be furnished provided such pipe complies with all other requirements of this specification.

NOTE 1—Acceptability for many services may be controlled by codes or standards such as those published by the American National Standards Institute and American Society of Mechanical Engineers.

NOTE 2—For testing methods not specifically covered in this specification, reference can be made to Test Methods and Definitions A 370, with particular reference to Annex A2 on Steel Tubular Products.

NOTE 3—A comprehensive listing of standardized pipe dimensions is contained in ANSI B 36.10.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

NOTE 4—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 The following caveat pertains specifically to Section 5 of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 36/A 36M Specification for Carbon Structural Steel

A 283/A 283M Specification for Low and Intermediate Tensile Strength Carbon Steel Plates

A 285/A 285M Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 570/A 570M Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled[3]

2.2 *ASME Boiler and Pressure Vessel Code:*

Section IX Welding Qualifications [4]

2.3 *American National Standards Institute Standard:*

B 16.25 Buttwelding Ends[5]

B 36.10 Welded and Seamless Wrought Steel Pipe[5]

3. Ordering Information

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

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

3.1.2 Name of material (electric-fusion (arc)-welded pipe),

3.1.3 Grade (Section 4),

3.1.4 Size (inside or outside diameter and nominal wall thickness),

3.1.5 Length (specified or random),

3.1.6 Specific straightness requirements (see 12.3),

3.1.7 End finish (Section 15),

3.1.8 Hydrostatic test pressure (Section 11),

3.1.9 ASTM designation, and

3.1.10 End use of material.

4. Material

4.1 The steel from which the pipe is made shall conform to Specifications A 283/A 283M, A 285/A 285M, A 570/A 570M, or A 36/A 36M or to other ASTM specifications for equally suitable weldable material, as specified. For purposes of marking and certification, when required, the pipe grade of

[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 A01.09 on Carbon Steel Tubular Products.

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[2] 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.

[3] Withdrawn.

[4] Available from American Society of Mechanical Engineers, 345 E. 47th St. New York, NY 10017.

[5] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

material shall be established by the A xxx plate specification designation and plate grade, when applicable.

5. Manufacture

5.1 The longitudinal edges of the steel shall be shaped to give the most satisfactory results by the particular welding process employed. The steel shall then be properly formed and may be tacked preparatory to welding. The weld shall be made by automatic means (except tack welds) and shall be of reasonably uniform width and height for the entire length of the pipe. By agreement between the purchaser and the manufacturer, manual welding by qualified procedure and welders may be used as an equal alternate under this specification.

5.2 All longitudinal seams, spiral seams, and shop girth seams shall be butt-welded.

6. Number of Production Weld Tests

6.1 One weld test specimen specified in Section 8 shall be made from each lot of 3000 ft (900 m) of pipe or fraction thereof of each size and wall thickness.

6.2 If any test specimen shows defective machining or develops flaws not associated with the welding, it may be discarded and another specimen substituted.

6.3 Each length of pipe shall be subjected to the hydrostatic test specified in Section 11, unless otherwise specified in 11.3.

7. Retests

7.1 If any specimen tested in accordance with Section 10 fails to meet the requirements, retests of two additional specimens from the same lot of pipe shall be made, each of which shall meet the requirements specified. If any of the retests fail to conform to the requirements, test specimens may be taken from each untested pipe length at the manufacturer's option. Each specimen shall meet the requirements specified, or that pipe shall be rejected.

8. Test Specimens of Production Welds

8.1 The weld-test specimens for the reduced-section tension test shall be taken perpendicularly across the weld and from the end of the pipe or, alternatively, from flat test pieces of material conforming to the requirements in the specifications used in the manufacture of the pipe. The alternative weld-test specimens shall be welded with the same procedure and by the same operator and equipment, and in sequence with the welding of the longitudinal joints in the pipe. The test pieces shall have the weld approximately in the middle of the specimen. The specimens shall be straightened cold, and shall be tested at room temperature.

8.2 Reduced-section tension-test specimens shall be prepared in accordance with Fig. 21 of Test Methods and Definitions A 370.

9. Qualification of Welding Procedure

9.1 The welding procedure shall be qualified in accordance with the American Welding Society Standard Qualification Procedure[6] or ASME Section IX of the Boiler and Pressure Vessel Code as agreed to between the manufacturer and the purchaser using the tests and test values specified in 9.2 and 9.3. Thicknesses less than ⅜ in. (10 mm) shall be qualified for each wall thickness of pipe manufactured. Thicknesses ⅜ to ¾ in. (10 mm to 19.0 mm), inclusive, shall be qualified in ⅜-in. (10-mm) thickness.

9.2 Two reduced-section tension specimens (transverse weld) made in accordance with Fig. 21 of Test Methods and Definitions A 370, with the weld reinforcement removed, shall show a tensile strength not less than 100 % of the minimum specified tensile strength of the base material used.

9.3 Two face-bend test specimens shall be prepared in accordance with Fig. 2(a) of Test Methods and Definitions A 370 and shall withstand being bent 180° in a jig substantially in accordance with Fig. 30 of Test Methods and Definitions A 370. The bend test shall be acceptable if no cracks or other defects exceeding ⅛ in. (3.2 mm) in any direction be present in the weld metal or between the weld and the pipe metal after bending. Cracks that originate along the edges of the specimens during testing and that are less than ¼ in. (6.3 mm) in any direction, shall not be considered.

10. Tensile Properties of Production Welds

10.1 Reduced-section tension test specimens required in Section 8, taken perpendicularly across the weld with the weld reinforcement removed, shall show a tensile strength not less than 95 % of the specified minimum strength of the steel. At the manufacturer's option, the test may be made without removing the weld reinforcement, in which case the tensile strength shall be not less than the specified minimum tensile strength for the grade of steel used.

11. Hydrostatic Test (Note 5)

11.1 Each length of pipe shall be tested by the manufacturer to a hydrostatic pressure that will produce in the pipe wall a stress of 60 % of the specified minimum yield point of the steel used at room temperature. The pressure shall be determined by the following equation:

$$P = 2St / D$$

where:

P = minimum hydrostatic test pressure, psi (Note 6) (not to exceed 2800 psi (19 MPa)),
S = 0.60 times the minimum specified yield point of the steel used, psi (MPa),
t = specified wall thickness, in. (mm), and
D = specified outside diameter, in. (mm).

NOTE 5—A hydrostatic sizing operation is not to be considered a

[6] Available from American Welding Society, 550 N.W. LeJeune Rd., Miami, FL 33135.

hydrostatic test or a substitute for it.

NOTE 6—When the diameter and wall thickness of pipe are such that the capacity limits of testing equipment are exceeded by these requirements, the test pressures may be reduced by agreement between the purchaser and the manufacturer.

11.2 Test pressure shall be held for not less than 5 s, or for a longer time as agreed upon between the purchaser and the manufacturer.

NOTE 7—When agreed upon between the purchaser and the manufacturer and so stated on the order, pipe may be tested to one and one half times the specified working pressure, except that the maximum test pressure shall not exceed 2800 psi (19 MPa) nor shall the maximum fiber stress exceed 85 % of specified minimum yield point of steel or to a fiber stress that does not exceed 85 % of the specified minimum yield point of the steel or 2800-psi (19-MPa) test pressure.

11.3 When specified in the order, pipe may be furnished without hydrostatic testing and each length so furnished shall include the mandatory marking of the letters "NH." Additionally, the certification, when required, shall state "Not Hydrostatically Tested" and the specification number and material grade, as shown on the certification, shall be followed by the letters "NH."

12. Permissible Variations in Weights and Dimensions

12.1 *Thickness and Weight*—The wall thickness and weight for welded pipe under this specification shall be governed by the requirements of the specifications to which the steel was ordered.

12.2 *Circumference*—The outside circumference of the pipe shall not vary more than ±0.5 % from the nominal outside circumference based upon the diameter specified, except that the circumference at ends shall be sized, if necessary, to meet the requirements of Section 14.

12.3 *Straightness*—Finished pipe shall be commercially straight. When specific straightness requirements are desired, the order should so state, and the tolerances shall be a matter of agreement between the purchaser and the manufacturer.

12.4 *Ovality—Out-of-roundness*—The difference between major and minor outside diameter shall not exceed 1 %. Closer tolerances may be established by agreement between the manufacturer and the purchaser. Where the *D/T* (outside diameter/wall thickness) is over 120, internal bracing should be utilized to achieve sizing of ends and ovality shall be by agreement between the manufacturer and purchaser.

13. Lengths

13.1 Pipe lengths shall be supplied in accordance with the following regular practice:

13.1.1 The lengths shall be as specified on the order with a tolerance of ±½ in. (13 mm), except that the shorter lengths from which test coupons have been cut may also be shipped.

13.1.2 When random lengths are specified, pipe shall be furnished in lengths having a minimum average of 29 ft (9 m) with a minimum length of 20 ft (6 m), but not more than 5 % may be under 25 ft (8 m).

13.2 Pipe lengths containing circumferentially welded joints (Note 8) shall be permitted by agreement between the manufacturer and the purchaser. Tests of these welded joints shall be made in accordance with the procedure tests specified in Section 9 and the production weld tests specified in Section 10. The number of production weld tests shall be one per each lot of 100 joints or fraction thereof, but not less than one for each welder or welding operator.

NOTE 8—Joints are defined for the purpose of this specification as a circumferential welded seam lying in one plane, used to join lengths of straight pipe.

14. Ends

14.1 Pipe shall be furnished with a plain right-angle cut or with bevel ends as specified. All burrs at the ends of pipe shall be removed.

14.1.1 Unless otherwise specified, pipe with beveled ends shall meet the requirements of ANSI B 16.25.

14.2 Unless otherwise specified, the outside circumference of pipe ends for a distance of not less than 4 in. (100 mm) shall not vary more than ±60 % of the nominal wall thickness of the pipe from the nominal outside circumference based on the diameter specified, except that the tolerance shall not be less than ±3⁄16 in. (5 mm).

14.3 By agreement between the manufacturer and the purchaser the ends of the pipe may be sized within agreed-upon tolerances if necessary to meet the requirements of special installations.

15. Finish

15.1 *Repair by Welding*—The welding of injurious defects in the pipe wall, provided their depth does not exceed one third the specified wall thickness, will be permitted. Defects in the welds, such as sweats or leaks, shall be repaired or the piece rejected at the option of the manufacturer. Repairs of this nature shall be made by completely removing the defect, cleaning the cavity, and then welding.

15.2 All repaired pipe shall be tested hydrostatically in accordance with Section 11, unless otherwise specified in 11.3.

16. Inspection

16.1 The inspector representing the purchaser shall have entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be made at the place of manufacture prior to shipment and unless otherwise specified, shall be so conducted as not to interfere unnecessarily with the operation of the works. If agreed upon, the manufacturer shall notify the purchaser in time so that he may have his inspector present to witness any part of the manufacture or tests that may be desired. The certification shall include reference to this specification and the pipe grade (ASTM plate specification designation and plate grade, when applicable).

16.2 *Certification*—Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the chemical and tensile tests shall be furnished. When hydrostatic test is omitted, the certificate shall include the letters "NH."

17. Rejection

17.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of this specification based on the inspection and test method as outlined in the specification, the length may be rejected, and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

17.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, may be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter of agreement between the purchaser and the manufacturer.

18. Certification

18.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, including year date, together with a report of the chemical and tensile tests shall be furnished. The pipe grade shall be identified by the plate specification designation (year date not required) and the plate grade (where applicable).

19. Product Marking

19.1 Each section of pipe shall be marked with the manufacturer's distinguishing marking, this specification number, and the pipe grade. The marking need not include the year date of the pipe or plate specification.

19.2 *Bar Coding*—In addition to the requirements in 19.1, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

20. Protective Coating

20.1 If agreed upon between the purchaser and the manufacturer, the pipe shall be given a protective coating of the kind and in the manner specified by the purchaser.

Designation: A 106/A 106M – 06a

Used in USDOE-NE standards

Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service[1]

This standard is issued under the fixed designation A 106/A 106M; 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*

1.1 This specification[2] covers seamless carbon steel pipe for high-temperature service (Note 1) in NPS ⅛ to NPS 48 [DN 6 to DN 1200] (Note 2) inclusive, with nominal (average) wall thickness as given in ASME B 36.10M. It shall be permissible to furnish pipe having other dimensions provided such pipe complies with all other requirements of this specification. Pipe ordered under this specification shall be suitable for bending, flanging, and similar forming operations, and for welding. When the steel is to be welded, it is presupposed that a welding procedure suitable to the grade of steel and intended use or service will be utilized.

NOTE 1—It is suggested, consideration be given to possible graphitization.

NOTE 2—The dimensionless designator NPS (nominal pipe size) [DN (diameter nominal)] has been substituted in this standard for such traditional terms as "nominal diameter," "size," and "nominal size."

1.2 Supplementary requirements of an optional nature are provided for seamless pipe intended for use in applications where a superior grade of pipe is required. These supplementary requirements call for additional tests to be made and when desired shall be so stated in the order.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents. Therefore, each system is to be used independently of the other.

1.4 The following precautionary caveat pertains only to the test method portion, Sections 11, 12, and 13 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy 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 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *ASME Standard:*

ASME B 36.10M Welded and Seamless Wrought Steel Pipe[4]

2.3 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[5]

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage[5]

2.4 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[5]

Fed. Std. No. 183 Continuous Identification Marking of Iron and Steel Products[5]

2.5 *Other Standards:*

SSPC-SP 6 Surface Preparation Specification No. 6[6]

3. Ordering Information

3.1 The inclusion of the following, as required will describe the desired material adequately, when ordered under this specification:

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

[1] This specification is under the jurisdiction of Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.09 on Carbon Steel Tubular Products.

Current edition approved Oct. 1, 2006. Published October 2006. Originally approved in 1926. Last previous edition in 2006 as A 106/A 106M – 06.

[2] For ASME Boiler and Pressure Vessel Code applications see related Specifications SA-106 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, Three Park Ave., New York, NY 10016-5990.

[5] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.

[6] Available from Steel Structures Painting Council (SSPC), 40 24th St., 6th Floor, Pittsburgh, PA 15222-4656.

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

3.1.2 Name of material (seamless carbon steel pipe),
3.1.3 Grade (Table 1),
3.1.4 Manufacture (hot-finished or cold-drawn),
3.1.5 Size (NPS [DN] and weight class or schedule number, or both; outside diameter and nominal wall thickness; or inside diameter and nominal wall thickness),
3.1.6 Special outside diameter tolerance pipe (16.2.2),
3.1.7 Inside diameter tolerance pipe, over 10 in. [250 mm] ID (16.2.3),
3.1.8 Length (specific or random, Section 17),
3.1.9 Optional requirements (Section 9 and S1 to S8),
3.1.10 Test report required (Section on Certification of Specification A 530/A 530M),
3.1.11 Specification designation (A 106 or A 106M, including year-date),
3.1.12 End use of material,
3.1.13 Hydrostatic test in accordance with Specification A 530/A 530M or 13.3 of this specification, or NDE in accordance with Section 14 of this specification.
3.1.14 Special requirements.

4. Process

4.1 The steel shall be killed steel, with the primary melting process being open-hearth, basic-oxygen, or electric-furnace, possibly combined with separate degassing or refining. If secondary melting, using electroslag remelting or vacuum-arc remelting is subsequently employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.2 Steel cast in ingots or strand cast is permissible. When steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by any established procedure that positively separates the grades.

4.3 For pipe NPS 1½ [DN 40] and under, it shall be permissible to furnish hot finished or cold drawn.

4.4 Unless otherwise specified, pipe NPS 2 [DN 50] and over shall be furnished hot finished. When agreed upon between the manufacturer and the purchaser, it is permissible to furnish cold-drawn pipe.

5. Heat Treatment

5.1 Hot-finished pipe need not be heat treated. Cold-drawn pipe shall be heat treated after the final cold draw pass at a temperature of 1200 °F (650 °C) or higher.

TABLE 1 Chemical Requirements

	Composition, %		
	Grade A	Grade B	Grade C
Carbon, max[A]	0.25	0.30	0.35
Manganese	0.27–0.93	0.29–1.06	0.29–1.06
Phosphorus, max	0.035	0.035	0.035
Sulfur, max	0.035	0.035	0.035
Silicon, min	0.10	0.10	0.10
Chrome, max[B]	0.40	0.40	0.40
Copper, max[B]	0.40	0.40	0.40
Molybdenum, max[B]	0.15	0.15	0.15
Nickel, max[B]	0.40	0.40	0.40
Vanadium, max[B]	0.08	0.08	0.08

[A] For each reduction of 0.01 % below the specified carbon maximum, an increase of 0.06 % manganese above the specified maximum will be permitted up to a maximum of 1.35 %.
[B] These five elements combined shall not exceed 1 %.

6. General Requirements

6.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification A 530/A 530M unless otherwise provided herein.

7. Chemical Composition

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

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified in Section 7. If the secondary melting processes of 5.1 are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The chemical composition thus determined, or that determined from a product analysis made by the manufacturer, if the latter has not manufactured the steel, shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 7.

9. Product Analysis

9.1 At the request of the purchaser, analyses of two pipes from each lot (see 20.1) shall be made by the manufacturer from the finished pipe. The results of these analyses shall be reported to the purchaser or the purchaser's representative and shall conform to the requirements specified in Section 7.

9.2 If the analysis of one of the tests specified in 9.1 does not conform to the requirements specified in Section 7, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to requirements specified.

10. Tensile Requirements

10.1 The material shall conform to the requirements as to tensile properties given in Table 2.

11. Bending Requirements

11.1 For pipe NPS 2 [DN 50] and under, a sufficient length of pipe shall stand being bent cold through 90° around a cylindrical mandrel, the diameter of which is twelve times the outside diameter (as shown in ASME B 36.10M) of the pipe, without developing cracks. When ordered for close coiling, the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the outside diameter (as shown in ASME B 36.10M) of the pipe, without failure.

11.2 For pipe whose diameter exceeds 25 in. [635 mm] and whose diameter to wall thickness ratio, where the diameter to wall thickness ratio is the specified outside diameter divided by the nominal wall thickness, is 7.0 or less, the bend test shall be conducted. The bend test specimens shall be bent at room temperature through 180° with the inside diameter of the bend being 1in. [25 mm] without cracking on the outside portion of the bent portion.

Example: For 28 in. [711 mm] diameter 5.000 in. [127 mm] thick pipe the diameter to wall thickness ratio = 28/5 = 5.6 [711/127 = 5.6].

TABLE 2 Tensile Requirements

	Grade A		Grade B		Grade C	
Tensile strength, min, psi [MPa]	48 000 [330]		60 000 [415]		70 000 [485]	
Yield strength, min, psi [MPa]	30 000 [205]		35 000 [240]		40 000 [275]	
	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
Elongation in 2 in. [50 mm], min, %:						
Basic minimum elongation transverse strip tests, and for all small sizes tested in full section	35	25	30	16.5	30	16.5
When standard round 2-in. [50-mm] gage length test specimen is used	28	20	22	12	20	12
For longitudinal strip tests	[A]		[A]		[A]	
For transverse strip tests, a deduction for each 1⁄32-in. [0.8-mm] decrease in wall thickness below 5⁄16 in. [7.9 mm] from the basic minimum elongation of the following percentage shall be made		1.25		1.00		1.00

[A] The minimum elongation in 2 in. [50 mm] shall be determined by the following equation:

$$e = 625\ 000 A^{0.2} / U^{0.9}$$

for SI units, and

$$e = 1\ 940 A^{0.2} / U^{0.9}$$

for inch-pound units,

where:

e = minimum elongation in 2 in. [50 mm], %, rounded to the nearest 0.5 %,

A = cross-sectional area of the tension test specimen, in.^{2} [mm^2], based upon specified outside diameter or nominal specimen width and specified wall thickness, rounded to the nearest 0.01 in.^{2} [1 mm^2]. (If the area thus calculated is equal to or greater than 0.75 in.^{2} [500 mm^2], then the value 0.75 in.^{2} [500 mm^2] shall be used.), and

U = specified tensile strength, psi [MPa].

12. Flattening Tests

12.1 Although testing is not required, pipe shall be capable of meeting the flattening test requirements of Supplementary Requirement S3, if tested.

13. Hydrostatic Test

13.1 Except as allowed by 13.2, 13.3, and 13.4, each length of pipe shall be subjected to the hydrostatic test without leakage through the pipe wall.

13.2 As an alternative to the hydrostatic test at the option of the manufacturer or where specified in the purchase order, it shall be permissible for the full body of each pipe to be tested with a nondestructive electric test described in Section 14.

13.3 Where specified in the purchase order, it shall be permissible for pipe to be furnished without the hydrostatic test and without the nondestructive electric test in Section 14; in this case, each length so furnished shall include the mandatory marking of the letters "NH." It shall be permissible for pipe meeting the requirements of 13.1 or 13.2 to be furnished where pipe without either the hydrostatic or nondestructive electric test has been specified in the purchase order; in this case, such pipe need not be marked with the letters "NH." Pipe that has failed either the hydrostatic test of 13.1 or the nondestructive electric test of 13.2 shall not be furnished as "NH" pipe.

13.4 Where the hydrostatic test and the nondestructive electric test are omitted and the lengths marked with the letters "NH," the certification, where required, shall clearly state "Not Hydrostatically Tested," and the letters "NH" shall be appended to the product specification number and material grade shown on the certification.

14. Nondestructive Electric Test

14.1 As an alternative to the hydrostatic test at the option of the manufacturer or where specified in the purchase order as an alternative or addition to the hydrostatic test, the full body of each pipe shall be tested with a nondestructive electric test in accordance with Practice E 213, E 309, or E 570. In such cases, the marking of each length of pipe so furnished shall include the letters "NDE." It is the intent of this nondestructive electric test to reject pipe with imperfections that produce test signals equal to or greater than that produced by the applicable calibration standard.

14.2 Where the nondestructive electric test is performed, the lengths shall be marked with the letters "NDE." The certification, where required, shall state "Nondestructive Electric Tested" and shall indicate which of the tests was applied. Also, the letters "NDE" shall be appended to the product specification number and material grade shown on the certification.

14.3 The following information is for the benefit of the user of this specification:

14.3.1 The reference standards defined in 14.4 through 14.6 are convenient standards for calibration of nondestructive testing equipment. The dimensions of such standards are not to be construed as the minimum sizes of imperfections detectable by such equipment.

14.3.2 The ultrasonic testing referred to in this specification is capable of detecting the presence and location of significant longitudinally or circumferentially oriented imperfections: however, different techniques need to be employed for the detection of such differently oriented imperfections. Ultrasonic testing is not necessarily capable of detecting short, deep imperfections.

14.3.3 The eddy current examination referenced in this specification has the capability of detecting significant imperfections, especially of the short abrupt type.

14.3.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented imperfections: however, different techniques need to be employed for the detection of such differently oriented imperfections.

14.3.5 The hydrostatic test referred to in Section 13 has the capability of finding defects of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. Hydrostatic testing is not necessarily capable of detecting very tight, through-the-wall imperfections or imperfections that extend an appreciable distance into the wall without complete penetration.

14.3.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of discontinuities that can be detected in the specific applications of these examinations is directed to discuss this with the manufacturer of the tubular product.

14.4 For ultrasonic testing, the calibration reference notches shall be, at the option of the producer, any one of the three common notch shapes shown in Practice E 213. The depth of notch shall not exceed 12½ % of the specified wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater.

14.5 For eddy current testing, the calibration pipe shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection:

14.5.1 *Drilled Hole*—The calibration pipe shall contain depending upon the pipe diameter three holes spaced 120° apart or four holes spaced 90° apart and sufficiently separated longitudinally to ensure separately distinguishable responses. The holes shall be drilled radially and completely through the pipe wall, care being taken to avoid distortion of the pipe while drilling. Depending upon the pipe diameter the calibration pipe shall contain the following hole:

NPS	DN	Diameter of Drilled Hole
≤ ½	≤ 15	0.039 in. [1 mm]
> ½ ≤ 1¼	> 15 ≤ 32	0.055 in. [1.4 mm]
> 1¼ ≤ 2	> 32 ≤ 50	0.071 in. [1.8 mm]
> 2 ≤ 5	> 50 ≤ 125	0.087 in. [2.2 mm]
>5	> 125	0.106 in. [2.7 mm]

14.5.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼-in. [6-mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. The notch shall have a depth not exceeding 12 ½ % of the specified wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is greater.

14.5.3 *Longitudinal Notch*—A notch 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the pipe, to have a depth not exceeding 12 ½ % of the specified wall thickness of the tube or 0.004 in. [0.1 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

14.5.4 *Compatibility*—The discontinuity in the calibration pipe shall be compatible with the testing equipment and the method being used.

14.6 For flux leakage testing, the longitudinal calibration reference notches shall be straight-sided notches machined in a radial plane parallel to the pipe axis. For wall thicknesses under ½ in. [12.7 mm], outside and inside notches shall be used; for wall thicknesses equal to and above ½ in. [12.7 mm], only an outside notch shall be used. Notch depth shall not exceed 12½ % of the specified wall thickness, or 0.004 in. [0.1 mm], whichever is greater. Notch length shall not exceed 1 in. [25 mm], and the width shall not exceed the depth. Outside diameter and inside diameter notches shall be located sufficiently apart to allow separation and identification of the signals.

14.7 Pipe containing one or more imperfections that produce a signal equal to or greater than the signal produced by the calibration standard shall be rejected or the area producing the signal shall be reexamined.

14.7.1 Test signals produced by imperfections which cannot be identified, or produced by cracks or crack-like imperfections shall result in rejection of the pipe, unless it is repaired and retested. To be accepted, the pipe must pass the same specification test to which it was originally subjected, provided that the remaining wall thickness is not decreased below that permitted by this specification. The OD at the point of grinding may be reduced by the amount so reduced.

14.7.2 Test signals produced by visual imperfections such as those listed below may be evaluated in accordance with the provisions of Section 18:

14.7.2.1 Dinges,

14.7.2.2 Straightener marks,

14.7.2.3 Cutting chips,

14.7.2.4 Scratches,

14.7.2.5 Steel die stamps,

14.7.2.6 Stop marks, or

14.7.2.7 Pipe reducer ripple.

14.8 The test methods described in this section are not necessarily capable of inspecting the end portion of pipes, a condition referred to as "end effect." The length of such end effect shall be determined by the manufacturer and, when specified in the purchase order, reported to the purchaser.

15. Nipples

15.1 Nipples shall be cut from pipe of the same dimensions and quality described in this specification.

16. Dimensions, Mass, and Permissible Variations

16.1 *Mass*—The mass of any length of pipe shall not vary more than 10 % over and 3.5 % under that specified. Unless otherwise agreed upon between the manufacturer and the purchaser, pipe in NPS 4 [DN 100] and smaller may be weighed in convenient lots; pipe larger than NPS 4 [DN 100] shall be weighed separately.

16.2 *Diameter*—The tolerances for diameter shall be in accordance with the following:

16.2.1 Except for pipe ordered as special outside diameter tolerance pipe or as inside diameter tolerance pipe, variations in outside diameter shall not exceed those given in Table 3.

16.2.2 For pipe over 10 in. [250 mm] OD ordered as special outside diameter tolerance pipe, the outside diameter shall not vary more than 1 % over or 1 % under the specified outside diameter.

16.2.3 For pipe over 10 in. [250 mm] ID ordered as inside diameter tolerance pipe, the inside diameter shall not vary more than 1 % over or 1 % under the specified inside diameter.

16.3 *Thickness*—The minimum wall thickness at any point shall not be more than 12.5 % under the specified wall thickness.

17. Lengths

17.1 Pipe lengths shall be in accordance with the following regular practice:

17.1.1 The lengths required shall be specified in the order, and

TABLE 3 Variations in Outside Diameter

NPS [DN Designator]	Permissible Variations in Outside Diameter			
	Over		Under	
	in.	mm	in.	mm
1⁄8 to 1½ [6 to 40], incl	1⁄64 (0.015)	0.4	1⁄64 (0.015)	0.4
Over 1½ to 4 [40 to 100], incl	1⁄32 (0.031)	0.8	1⁄32 (0.031)	0.8
Over 4 to 8 [100 to 200], incl	1⁄16 (0.062)	1.6	1⁄32 (0.031)	0.8
Over 8 to 18 [200 to 450], incl	3⁄32 (0.093)	2.4	1⁄32 (0.031)	0.8
Over 18 to 26 [450 to 650], incl	1⁄8 (0.125)	3.2	1⁄32 (0.031)	0.8
Over 26 to 34 [650 to 850], incl	5⁄32 (0.156)	4.0	1⁄32 (0.031)	0.8
Over 34 to 48 [850 to 1200], incl	3⁄16 (0.187)	4.8	1⁄32 (0.031)	0.8

17.1.2 No jointers are permitted unless otherwise specified.

17.1.3 If definite lengths are not required, pipe may be ordered in single random lengths of 16 to 22 ft [4.8 to 6.7 m] with 5 % 12 to 16 ft [3.7 to 4.8 m], or in double random lengths with a minimum average of 35 ft [10.7 m] and a minimum length of 22 ft [6.7 m] with 5 % 16 to 22 ft [4.8 to 6.7 m].

18. Workmanship, Finish and Appearance

18.1 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 consideration should be given to the necessity of exploring all surface imperfections to assure compliance with 18.2.

18.2 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:

18.2.1 The defect shall be removed by grinding, provided that the remaining wall thickness is within the limits specified in 16.3.

18.2.2 Repaired in accordance with the repair welding provisions of 18.6.

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

18.2.4 Rejected.

18.3 To provide a workmanlike finish and basis for evaluating conformance with 18.2 the pipe manufacturer shall remove by grinding the following noninjurious imperfections:

18.3.1 Mechanical marks and abrasions—such as cable marks, dinges, guide marks, roll marks, ball scratches, scores, and die marks—and pits, any of which imperfections are deeper than 1⁄16 in. [1.6 mm].

18.3.2 Visual imperfections commonly referred to as scabs, seams, laps, tears, or slivers found by exploration in accordance with 18.1 to be deeper than 5 % of the nominal wall thickness.

18.4 At the purchaser's discretion, pipe shall be subjected to rejection if surface imperfections acceptable under 18.2 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.

18.5 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 is permitted to be reduced by the amount so removed.

18.5.1 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.

18.6 Weld repair shall be permitted only subject to the approval of the purchaser and in accordance with Specification A 530/A 530M.

18.7 The finished pipe shall be reasonably straight.

19. End Finish

19.1 The Pipe shall be furnished to the following practice, unless otherwise specified.

19.1.1 *NPS 1½ [DN 40] and Smaller*—All walls shall be either plain-end square cut, or plain-end beveled at the option of the manufacturer.

19.1.2 *NPS 2 [DN 50] and Larger*—Walls through extra strong weights, shall be plain-end-beveled.

19.1.3 *NPS 2 [DN 50] and Larger*—Walls over extra strong weights, shall be plain-end square cut.

19.2 Plain-end beveled pipe shall be plain-end pipe having a bevel angle of 30°, + 5° or - 0°, as measured from a line drawn perpendicular to the axis of the pipe with a root face of $\frac{1}{16} \pm \frac{1}{32}$ in. [1.6 ± 0.8 mm]. Other bevel angles may be specified by agreement between the purchaser and the manufacturer.

20. Sampling

20.1 For product analysis (see 9.1) and tensile tests (see 21.1), a lot is the number of lengths of the same size and wall thickness from any one heat of steel; of 400 lengths or fraction thereof, of each size up to, but not including, NPS 6 [DN 150]; and of 200 lengths or fraction thereof of each size NPS 6 [DN 150] and over.

20.2 For bend tests (see 21.2), a lot is the number of lengths of the same size and wall thickness from any one heat of steel, of 400 lengths or fraction thereof, of each size.

20.3 For flattening tests, a lot is the number of lengths of the same size and wall thickness from any one heat of steel, of 400 lengths or fraction thereof of each size over NPS 2 [DN 50], up to but not including NPS 6 [DN 150], and of 200 lengths or fraction thereof, of each size NPS 6 [DN 150] and over.

21. Number of Tests

21.1 The tensile requirements specified in Section 10 shall be determined on one length of pipe from each lot (see 20.1).

21.2 For pipe NPS 2 [DN 50] and under, the bend test specified in 11.1 shall be made on one pipe from each lot (see 20.2). The bend test, where used as required by 11.2, shall be made on one end of 5 % of the pipe from each lot. For small lots, at least one pipe shall be tested.

21.3 If any test specimen shows flaws or defective machining, it shall be permissible to discard it and substitute another test specimen.

22. Retests

22.1 If the percentage of elongation of any tension test specimen is less than that given in Table 1 and any part of the fracture is more than ¾ in. [19 mm] from the center of the gage length of a 2-in. [50-mm] specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed. If a specimen breaks in an inside or outside surface flaw, a retest shall be allowed.

23. Test Specimens and Test Methods

23.1 On NPS 8 [DN 200] and larger, specimens cut either longitudinally or transversely shall be acceptable for the tension test. On sizes smaller than NPS 8 [DN 200], the longitudinal test only shall be used.

23.2 When round tension test specimens are used for pipe wall thicknesses over 1.0 in. [25.4 mm], the mid–length of the longitudinal axis of such test specimens shall be from a location midway between the inside and outside surfaces of the pipe.

23.3 Test specimens for the bend test specified in Section 11 and for the flattening tests shall consist of sections cut from a pipe. Specimens for flattening tests shall be smooth on the ends and free from burrs, except when made on crop ends.

23.4 Test specimens for the bend test specified in 11.2 shall be cut from one end of the pipe and, unless otherwise specified, shall be taken in a transverse direction. One test specimen shall be taken as close to the outer surface as possible and another from as close to the inner surface as possible. The specimens shall be either ½ by ½ in. [12.5 by 12.5 mm] in section or 1 by ½ in. [25 by 12.5 mm] in section with the corners rounded to a radius not over $\frac{1}{16}$ in. [1.6 mm] and need not exceed 6 in. [150 mm] in length. The side of the samples placed in tension during the bend shall be the side closest to the inner and outer surface of the pipe respectively.

23.5 All routine check tests shall be made at room temperature.

24. Certification

24.1 When test reports are requested, in addition to the requirements of Specification A 530/A 530M, the producer or supplier shall furnish to the purchaser a chemical analysis report for the elements specified in Table 1.

25. Product Marking

25.1 In addition to the marking prescribed in Specification A 530/A 530M, the marking shall include heat number, the information as per Table 4, an additional symbol "S" if one or

TABLE 4 Marking

Hydro	NDE	Marking
Yes	No	Test Pressure
No	Yes	NDE
No	No	NH
Yes	Yes	Test Pressure/NDE

more of the supplementary requirements apply; the length, OD 1 %, if ordered as special outside diameter tolerance pipe; ID 1 %, if ordered as special inside diameter tolerance pipe; the schedule number, weight class, or nominal wall thickness; and, for sizes larger than NPS 4 [DN 100], the weight. Length shall be marked in feet and tenths of a foot [metres to two decimal places], depending on the units to which the material was ordered, or other marking subject to agreement. For sizes NPS 1½ , 1¼ , 1, and ¾ [DN 40, 32, 25, and 20], each length shall be marked as prescribed in Specification A 530/A 530M. These sizes shall be bundled in accordance with standard mill practice and the total bundle footage marked on the bundle tag; individual lengths of pipe need not be marked with footage. For sizes less than NPS ¾ [DN 20], all the required markings shall be on the bundle tag or on each length of pipe and shall include the total footage; individual lengths of pipe need not be marked with footage. If not marked on the bundle tag, all required marking shall be on each length.

25.2 When pipe sections are cut into shorter lengths by a subsequent processor for resale as material, the processor shall transfer complete identifying information, including the name or brand of the manufacturer to each unmarked cut length, or to metal tags securely attached to bundles of unmarked small diameter pipe. The same material designation shall be included with the information transferred, and the processor's name, trademark, or brand shall be added.

25.3 *Bar Coding*—In addition to the requirements in 25.1 and 25.2, bar coding is acceptable as a supplementary identification method. The purchaser may specify in the order a specific bar coding system to be used.

26. Government Procurement

26.1 When specified in the contract, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for the shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 or Fed. Std. No. 183 if continuous marking is required for military agencies.

26.2 *Inspection*—Unless otherwise specified in the contract, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the producer shall use his own, or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to ensure that the material conforms to the prescribed requirements.

27. Keywords

27.1 carbon steel pipe; seamless steel pipe; steel pipe

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test or analysis than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Product Analysis

S1.1 Product analysis shall be made on each length of pipe. Individual lengths failing to conform to the chemical composition requirements shall be rejected.

S2. Transverse Tension Test

S2.1 A transverse tension test shall be made on a specimen from one end or both ends of each pipe NPS 8 [DN 200] and over. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails to meet the required tensile properties (tensile, yield, and elongation), that length shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest.

S3. Flattening Test, Standard

S3.1 For pipe over NPS 2 [DN 50], a section of pipe not less than 2½ in. [63.5 mm] in length shall be flattened cold between parallel plates until the opposite walls of the pipe meet. Flattening tests shall be in accordance with Specification A 530/A 530M, except that in the formula used to calculate the "H" value, the following " e" constants shall be used:

0.08 for Grade A
0.07 for Grades B and C

S3.2 When low *D*-to-*t* ratio tubulars are tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the *D*-to-*t* ratio is less than ten.

S3.3 The flattening test shall be made on one length of pipe from each lot of 400 lengths or fraction thereof of each size over NPS 2 [DN 50], up to but not including NPS 6 [DN 150], and from each lot of 200 lengths or fraction thereof, of each size NPS 6 [DN 150] and over.

S3.4 Should a crop end of a finished pipe fail in the flattening test, one retest is permitted to be made from the failed end. Pipe shall be normalized either before or after the first test, but pipe shall be subjected to only two normalizing treatments.

S4. Flattening Test, Enhanced

S4.1 The flattening test of Specification A 530/A 530M shall be made on a specimen from one end or both ends of each pipe. Crop ends may be used. If this supplementary requirement is specified, the number of tests per pipe shall also be specified. If a specimen from any length fails because of lack of ductility prior to satisfactory completion of the first step of the flattening test requirement, that pipe shall be rejected subject to retreatment in accordance with Specification A 530/A 530M and satisfactory retest. If a specimen from any length of pipe fails because of a lack of soundness, that length shall be rejected, unless subsequent retesting indicates that the remaining length is sound.

S5. Metal Structure and Etching Test

S5.1 The steel shall be homogeneous as shown by etching tests conducted in accordance with the appropriate sections of Method E 381. Etching tests shall be made on a cross section from one end or both ends of each pipe and shall show sound and reasonably uniform material free from injurious laminations, cracks, and similar objectionable defects. If this supplementary requirement is specified, the number of tests per pipe required shall also be specified. If a specimen from any length shows objectionable defects, the length shall be rejected, subject to removal of the defective end and subsequent retests indicating the remainder of the length to be sound and reasonably uniform material.

S6. Carbon Equivalent

S6.1 The steel shall conform to a carbon equivalent (CE) of 0.50 maximum as determined by the following formula:

$$CE = \%C + \frac{\%Mn}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Ni + \%Cu}{15}$$

S6.2 A lower CE maximum may be agreed upon between the purchaser and the producer.

S6.3 The CE shall be reported on the test report.

S7. Heat Treated Test Specimens

S7.1 At the request of the purchaser, one tensile test shall be performed by the manufacturer on a test specimen from each heat of steel furnished which has been either stress relieved at 1250 °F or normalized at 1650 °F, as specified by the purchaser. Other stress relief or annealing temperatures, as appropriate to the analysis, may be specified by agreement between the purchaser and the manufacturer. The results of this test shall meet the requirements of Table 1.

S8. Internal Cleanliness–Government Orders

S8.1 The internal surface of hot finished ferritic steel pipe and tube shall be manufactured to a free of scale condition equivalent to the visual standard listed in SSPC-SP 6. Cleaning shall be performed in accordance with a written procedure that has been shown to be effective. This procedure shall be available for audit.

S9. Requirements for Carbon Steel Pipe for Hydrofluoric Acid Alkylation Service

S9.1 Pipe shall be provided in the normalized heat-treated condition.

S9.2 The carbon equivalent (CE), based upon 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].

S9.3 The carbon equivalent (CE) shall be determined using the following formula:

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

S9.4 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 %.

S9.5 Based upon heat analysis in mass percent, the sum of the nickel and copper contents shall not exceed 0.15 %.

S9.6 Based upon heat analysis in mass percent, the carbon content shall not be less than 0.18 %.

S9.7 Welding consumables of repair welds shall be of low hydrogen type. E60XX electrodes shall not be used and the resultant weld chemical composition shall meet the chemical composition requirements specified for the pipe.

S9.8 The designation "HF-N" shall be stamped or marked on each pipe to signify that the pipe complies with this supplementary requirement.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 106/A 106M – 06, that may impact the use of this specification. (Approved October 1, 2006)

(*1*) Revised 1.4.
(*2*) Revised 3.1.8.
(*3*) Deleted 11.2 and renumbered the subsequent paragraphs.
(*4*) Revised 11.2 (formerly 11.3).
(*5*) Revised Section 12.
(*6*) Deleted 21.3 and renumbered subsequent paragraphs.
(*7*) Deleted 22.2.
(*8*) Added new Supplementary Requirement S3 and renumbered subsequent sections.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 106/A 106M – 04b, that may impact the use of this specification. (Approved March 1, 2006)

(*1*) Deleted Note 3 and included its provisions in new Section 20.
(*2*) Deleted Note 4 and included its provisions in 11.2.
(*3*) Deleted Note 5 and included its provisions in 18.3.1.
(*4*) Deleted Note 6 and included its provisions in new paragraph 19.2.

Designation: A 105/A 105M – 05

Endorsed by
Manufacturers Standardization Society
of the Valve and Fittings Industry
Used in USDOE-NE Standards

Standard Specification for Carbon Steel Forgings for Piping Applications[1]

This standard is issued under the fixed designation A 105/A 105M; 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*

1.1 This specification[2] covers forged carbon steel piping components for ambient- and higher-temperature service in pressure systems. Included are flanges, fittings, valves, and similar parts ordered either to dimensions specified by the purchaser or to dimensional standards such as the MSS, ASME, and API specifications referenced in Section 2. Forgings made to this specification are limited to a maximum weight of 10 000 lb [4540 kg]. Larger forgings may be ordered to Specification A 266/A 266M. Tubesheets and hollow cylindrical forgings for pressure vessel shells are not included within the scope of this specification. Although this specification covers some piping components machined from rolled bar and seamless tubular products (see 4.2), it does not cover raw material produced in these product forms.

1.2 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.3 Specification A 266/A 266M covers other steel forgings and Specifications A 675/A 675M and A 696 cover other steel bars.

1.4 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.5 The values stated in either inch-pound units or SI 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.

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 In addition to those reference documents listed in Specification A 961, the following list of standards apply to this specification:

2.2 *ASTM Standards:* [3]

A 266/A 266M Specification for Carbon Steel Forgings for Pressure Vessel Components

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 675/A 675M Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties

A 696 Specification for Steel Bars, Carbon, Hot-Wrought or Cold-Finished, Special Quality, for Pressure Piping Components

A 788 Specification for Steel Forgings, General Requirements

A 961 Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

2.3 *MSS Standards:*

SP 44 Standard for Steel Pipe Line Flanges[4]

2.4 *ASME Standards:*

B16.5 Dimensional Standards for Steel Pipe Flanges and Flanged Fittings[5]

B16.9 Wrought Steel Buttwelding Fittings[5]

B16.10 Face-to-Face and End-to-End Dimensions of Ferrous Valves[5]

B16.11 Forged Steel Fittings, Socket Weld, and Threaded[5]

[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 A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-105 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 Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), 127 Park St., NE, Vienna, VA 22180-4602.

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990.

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

B16.34 Valves-Flanged, Threaded and Welding End[5]
B16.47 Large Diameter Steel Flanges[5]
2.5 *ASME Boiler and Pressure Vessel Code:*
Section IX Welding Qualifications[5]
2.6 *API Standards:*
API-600 Flanged and Butt-Welding-End Steel Gate Valves[6]
API-602 Compact Design Carbon Steel Gate Valves for Refinery Use[6]

3. Ordering Information

3.1 See Specification A 961.

3.1.1 Additional requirements (see 12.2).

4. General Requirements

4.1 Product furnished to this specification shall conform to the requirements of Specification A 961, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 961 constitutes nonconformance with this specification. In case of a conflict between the requirements of this specification and Specification A 961, this specification shall prevail.

4.2 Except as permitted by Section 6 in Specification A 961, the finished product shall be a forging as defined in the Terminology Section of Specification A 788.

5. Heat Treatment

5.1 Heat treatment is not a mandatory requirement of this specification except for the following piping components:

5.1.1 Flanges above Class 300,[7]

5.1.2 Flanges of special design where the design pressure at the design temperature exceeds the pressure-temperature ratings of Class 300, Group 1.1,

5.1.3 Flanges of special design where the design pressure or design temperature are not known,

5.1.4 Piping components other than flanges which meet both of the following criteria: (*1*) over NPS 4 and (*2*) above Class 300, and

5.1.5 Piping components of Special Class[8] other than flanges which meet both of the following criteria: (*1*) over NPS 4 and (*2*) when the working pressure at the operating temperature exceeds the tabulated values for Special Class 300, Group 1.1.

5.2 Heat treatment, when required by 5.1 shall be annealing, normalizing, or normalizing and tempering or quenching and tempering in accordance with Specification A 961.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements specified in Table 1.

6.2 Steels to which lead has been added shall not be used.

7. Mechanical Properties

7.1 The material shall conform to the mechanical property requirements prescribed in Table 2 and Table 3.

TABLE 1 Chemical Requirements

NOTE—For each reduction of 0.01 % below the specified carbon maximum (0.35 %), an increase of 0.06 % manganese above the specified maximum (1.05 %) will be permitted up to a maximum of 1.35 %.

Element	Composition, %
Carbon	0.35 max
Manganese	0.60–1.05
Phosphorus	0.035 max
Sulfur	0.040 max
Silicon	0.10–0.35
Copper	0.40 max^A
Nickel	0.40 max^A
Chromium	0.30 max^{A,B}
Molybdenum	0.12 max^{A,B}
Vanadium	0.08 max

^{A} The sum of copper, nickel, chromium, molybdenum and vanadium shall not exceed 1.00 %.
^{B} The sum of chromium and molybdenum shall not exceed 0.32 %.

TABLE 2 Mechanical Requirements^A

Tensile strength, min, psi [MPa]	70 000 [485]
Yield strength, min, psi [MPa]^B	36 000 [250]
Elongation in 2 in. or 50 mm, min, %:	
Basic minimum elongation for walls 5⁄16 in. [7.9 mm] and over in thickness, strip tests.	30
When standard round 2-in. or 50-mm gage length or smaller proportionally sized specimen with the gage length equal to 4D is used	22
For strip tests, a deduction for each 1⁄32-in. [0.8-mm] decrease in wall thickness below 5⁄16 in. [7.9 mm] from the basic minimum elongation of the percentage points of Table 3	1.50^C
Reduction of area, min, %^{D}	30
Hardness, HB, max	187

^{A} For small forgings, see 7.3.4.
^{B} Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.
^{C} See Table 3 for computed minimum values.
^{D} For round specimens only.

TABLE 3 Computed Minimum Values

Wall Thickness		Elongation in 2 in. or 50 mm, min, %
in.	mm	
5⁄16 (0.312)	7.9	30.00
9⁄32 (0.281)	7.1	28.50
1⁄4 (0.250)	6.4	27.00
7⁄32 (0.219)	5.6	25.50
3⁄16 (0.188)	4.8	24.00
5⁄32 (0.156)	4.0	22.50
1⁄8 (0.125)	3.2	21.00
3⁄32 (0.094)	2.4	19.50
1⁄16 (0.062)	1.6	18.00

NOTE—The above table 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 shown above, the minimum elongation value is determined by the following equation:

$$E = 48T + 15.00$$

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

7.2 For normalized, normalized and tempered, or quenched and tempered forgings, the central axis of the test specimen shall correspond to the 1⁄4 T plane or deeper position, where T is the maximum heat-treated thickness of the represented

[6] Available from The American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005.
[7] For definition of Class 300, see ASME B16.5.
[8] For definition of special class, see ASME B16.34.

forging. In addition, for quenched and tempered forgings, the midlength of the test specimen shall be at least *T* from any second heat-treated surface. When section thickness does not permit this positioning, the test specimen shall be positioned as near as possible to the prescribed location.

7.3 *Tension Tests*:

7.3.1 One tension test shall be made for each heat of as-forged components.

7.3.2 One tension test shall be made from each heat-treating charge. If more than one heat is included in such a charge, each heat shall be tested.

7.3.2.1 When the heat-treating temperatures are the same and the furnaces (either batch or continuous type), are controlled within ±25 °F [±14 °C] and equipped with recording pyrometers so that complete records of heat treatment are available, then one tension test from each heat is required instead of one test from each heat in each heat-treatment charge. The test specimen material shall be included with a furnace charge.

7.3.3 Testing shall be performed in accordance with Test Methods and Definitions A 370. The largest feasible round specimen as described in Test Methods and Definitions A 370 shall be used except when hollow cylindrically shaped parts are machined from seamless tubulars. The gage length for measuring elongation shall be four times the diameter of the test section. When hollow cylindrically shaped parts are machined from seamless tubular materials, strip tests may be used.

7.3.4 Forgings too small to permit obtaining a subsize specimen of 0.250 in. [6.35 mm] diameter or larger (see Test Methods and Definitions A 370) parallel to the dimension of maximum working, and produced in equipment unsuitable for the production of a separately forged test bar such as an automatic or semi-automatic press, may be accepted on the basis of hardness only. One percent of the forgings per lot (see Note 2), or ten forgings, whichever is the lesser number, shall be selected at random, prepared, and tested using the standard Brinell test in Test Methods and Definitions A 370. The locations of the indentations shall be at the option of the manufacturer but shall be selected to be representative of the forging as a whole. One indentation per forging shall be required but additional indentations may be made to establish the representative hardness. The hardness of all forgings so tested shall be 137 to 187 HB inclusive.

NOTE 2—A lot is defined as the product from a mill heat or if heat treated, the product of a mill heat per furnace charge.

7.4 *Hardness Tests*—Except when only one forging is produced, a minimum of two forgings shall be hardness tested per batch or continuous run as defined in 7.3.2.1 to ensure that forgings are within the hardness limits given in Table 2. When only one forging is produced, it shall be hardness tested as defined in 7.3.2.1 to ensure it is within the hardness limits given in Table 2. Testing shall be in accordance with Test Methods and Definitions A 370. The purchaser may verify that the requirement has been met by testing at any location on the forging, provided such testing does not render the forging useless.

8. Hydrostatic Tests

8.1 Such tests shall be conducted by the forging manufacturer only when Supplementary Requirement S8 in Specification A 961 is specified.

9. Retreatment

9.1 If the results of the mechanical tests do not conform to the requirement specified, the manufacturer may heat treat or reheat treat the forgings as applicable and repeat the test specified in Section 7.

10. Repair by Welding

10.1 Repair of defects by the manufacturer is permissible for forgings made to dimensional standards such as those of ASME or for other parts made for stock by the manufacturer. Prior approval of the purchaser is required to repair-weld special forgings made to the purchaser's requirements.

10.2 Weld repairs shall be made by a process that does not produce undesirably high levels of hydrogen in the welded areas.

10.3 All forgings repaired by welding shall be post-weld heat treated between 1100 °F [593 °C] and the lower transformation temperature for a minimum of ½ h/in. [½ h/25.4 mm] of maximum section thickness, or alternatively annealed, normalized and tempered, or quenched and tempered. If the forging was not previously heat treated, the original tempering temperature was exceeded, or the forging was fully heat treated in the post weld cycle, then the forging shall be tested in accordance with Section 7 on completion of the cycle.

10.4 The mechanical properties of the procedure-qualification weldment shall, when tested in accordance with Section IX of the ASME Boiler and Pressure Vessel Code, conform with the requirements listed in Table 2 for the thermal condition of repair-welded forgings.

11. Rejection and Rehearing

11.1 Each forging that develops injurious defects during shop working or application shall be rejected and the manufacturer notified.

12. Certification

12.1 *Identification Marking*—For forgings made to specified dimensions, when agreed upon by the purchaser, and for forgings made to dimensional standards, application of identification marks as required in Specification A 961 shall be the certification that the forgings have been furnished in accordance with the requirements of this specification. The specification designation included on test reports shall include year date and revision letter, if any.

12.2 *Test Reports*—When test reports are required, the manufacturer shall also provide the following, where applicable:

12.2.1 Type heat treatment, Section 5,

12.2.2 Tensile property results, Section 7 (Table 2), report the yield strength and ultimate strength, in ksi [MPa], elongation and reduction in area, in percent; and, if longitudinal strip tension specimens are used, report the width of the gage length, 12.2.3 Chemical analysis results, Section 6 (Table 1). When the amount of an unspecified element is less than 0.02 %, then the analysis for that element may be reported as "< 0.02 %,"

12.2.4 Hardness results, Section 7 (Table 2), and

12.2.5 Any supplementary testing required by the purchase order.

13. Product Marking

13.1 If the forgings have been quenched and tempered, the letters "QT" shall be stamped on the forgings following this specification number.

13.2 Forgings repaired by welding shall be marked with the letter "W" following this specification number.

13.3 When test reports are required for larger products, the markings shall consist of the manufacturer's symbol or name, this specification number, and such other markings as necessary to identify the part with the test report (13.1 and 13.2 shall apply). The specification number marked on the forgings need not include specification year date and revision letter.

13.4 *Bar Coding*—In addition to the requirements in Specification A 961 and 13.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

14. Keywords

14.1 pipe fittings, steel; piping applications; pressure containing parts; steel flanges; steel forgings, carbon; steel valves; temperature service applications, elevated; temperature service applications, high

SUPPLEMENTARY REQUIREMENTS

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

S1. Hardness

S1.1 The purchaser may check the hardness of any or all forgings supplied at any location on the forging and the hardness shall be 137 to 187 HB. All forgings not within the specified hardness range shall be rejected.

S2. Heat Treatment

S2.1 All forgings shall be heat treated as specified by the purchaser.

S2.2 When forgings not requiring heat treatment by 5.1 are supplied heat treated by purchaser request, the basis for determining conformance with Table 2 and Table 3 shall be hardness testing per 7.4 and either (*1*) tensile testing of heat treated forgings per 7.2, or (*2*) tensile tests from as-forged forgings or separately forged test blanks, as agreed upon between the supplier and purchaser.

S2.3 When test reports are required, and tensile test results were obtained from as-forged forgings or as-forged test blanks, it shall be so indicated on the test report.

S2.4 In addition to the marking required by Section 13, this specification shall be followed by the letter: A for annealed, N for normalized, NT for normalized and tempered, or QT for quenched and tempered, as appropriate.

S3. Marking Small Forgings

S3.1 For small products where the space for marking is less than 1 in. [25 mm] in any direction, test reports are mandatory and marking may be restricted to only such symbols or codes as are necessary to identify the parts with test reports.

S3.2 When the configuration or size does not permit marking directly on the forging, the marking method shall be a matter of agreement between the manufacturer and the purchaser.

S4. Carbon Equivalent

S4.1 The maximum carbon equivalent, based on heat analysis, shall be 0.47 for forgings with a maximum section thickness of 2 in. or less, and 0.48 for forgings with a maximum section thickness of greater than 2 in.

S4.2 Determine the carbon equivalent (CE) as follows:

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

S4.3 A lower maximum carbon equivalent may be agreed upon between the supplier and the purchaser.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 105/A 105M - 03, that may impact the use of this specification. (Approved June 1, 2005)

(*1*) Revised 12.2.2 to require reporting the width of the gage length of longitudinal strip tensile specimens, if they are used.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 105/A 105M - 02, that may impact the use of this specification. (Approved October 1, 2003)

(*1*) Deleted Columbium from Table 1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 105/A 105M - 01, that may impact the use of this specification. (Approved November 10, 2002)

(*1*) Deleted reference to Specification A 695 in 1.3 and 2.2.

Designation: A 53/A 53M – 07

Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless[1]

This standard is issued under the fixed designation A 53/A 53M; 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*

1.1 This specification[2] covers seamless and welded black and hot-dipped galvanized steel pipe in NPS ⅛ to NPS 26 [DN 6 to DN 650] (Note 1), inclusive, with nominal wall thickness (Note 2) as given in Table X2.2 and Table X2.3. It shall be permissible to furnish pipe having other dimensions provided that such pipe complies with all other requirements of this specification. Supplementary requirements of an optional nature are provided and shall apply only when specified by the purchaser.

NOTE 1—The dimensionless designators NPS (nominal pipe size) [DN (diameter nominal)] have been substituted in this specification for such traditional terms as "nominal diameter," "size," and "nominal size."

NOTE 2—The term nominal wall thickness has been assigned for the purpose of convenient designation, existing in name only, and is used to distinguish it from the actual wall thickness, which may vary over or under the nominal wall thickness.

1.2 This specification covers the following types and grades:

1.2.1 *Type F*—Furnace-butt-welded, continuous welded Grade A,

1.2.2 *Type E*—Electric-resistance-welded, Grades A and B, and

1.2.3 *Type S*—Seamless, Grades A and B.

NOTE 3—See Appendix X1 for definitions of types of pipe.

1.3 Pipe ordered under this specification is intended for mechanical and pressure applications and is also acceptable for ordinary uses in steam, water, gas, and air lines. It is suitable for welding, and suitable for forming operations involving coiling, bending, and flanging, subject to the following qualifications:

1.3.1 Type F is not intended for flanging.

1.3.2 If Type S or Type E is required for close coiling or cold bending, Grade A is the preferred grade; however, this is not intended to prohibit the cold bending of Grade B pipe.

1.3.3 Type E is furnished either nonexpanded or cold expanded at the option of the manufacturer.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system is to be used independently of the other.

1.5 The following precautionary caveat pertains only to the test method portion, Sections 7, 8, 9, 13, 14, and 15 of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

1.6 The text of this specification contains notes or footnotes, or both, that provide explanatory material. Such notes and footnotes, excluding those in tables and figures, do not contain any mandatory requirements.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 90/A 90M Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 530/A 530M Specification for General Requirements for Specialized Carbon and Alloy Steel Pipe

A 700 Practices for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A 865 Specification for Threaded Couplings, Steel, Black or Zinc-Coated (Galvanized) Welded or Seamless, for Use in Steel Pipe Joints

[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 A01.09 on Carbon Steel Tubular Products.

Current edition approved Sept. 1, 2007. Published October 2007. Originally approved in 1915. Last previous edition approved in 2006 as A 53/A 53M – 06a.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-53 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.

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

B 6 Specification for Zinc
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing
E 273 Practice for Ultrasonic Examination of the Weld Zone of Welded Pipe and Tubing
E 309 Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation
E 570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products
E 1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition

2.2 *ANSI Standards:*
ASC X12[4]
B1.20.1 Pipe Threads, General Purpose[4]

2.3 *ASME Standard:*
B36.10M Welded and Seamless Wrought Steel Pipe[5]

2.4 *Military Standards:*
MIL-STD-129 Marking for Shipment and Storage[6]
MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[6]

2.5 *Federal Standards:*
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[7]
Fed. Std. No 183 Continuous Identification Marking of Iron and Steel Products[7]

2.6 *API Standard:*
5B Specification for Threading, Gauging, and Thread Inspection of Casing, Tubing, and Line Pipe Threads[8]

3. Ordering Information

3.1 Information items to be considered, if appropriate, for inclusion in the purchase order are as follows:

3.1.1 Specification designation (A 53 or A 53M, including year-date),

3.1.2 Quantity (feet, metres, or number of lengths),

3.1.3 Grade (A or B),

3.1.4 Type (F, E, or S; see 1.2),

3.1.5 Finish (black or galvanized),

3.1.6 Size (either nominal (NPS) [DN] and weight class or schedule number, or both; or outside diameter and wall thickness, see Table X2.2 and Table X2.3),

3.1.7 Length (specific or random, see Section 16),

3.1.8 End finish (plain end or threaded, Section 11),

3.1.8.1 Threaded and coupled, if desired,

3.1.8.2 Threads only (no couplings), if desired,

3.1.8.3 Plain end, if desired,

3.1.8.4 Couplings power tight, if desired,

3.1.8.5 Taper-tapped couplings for NPS 2 [DN 50] and smaller, if desired,

3.1.9 Close coiling, if desired (see 7.2.2),

3.1.10 Nondestructive electric test for seamless pipe (see 9.2),

3.1.11 Certification (see Section 20),

3.1.12 Report of the length of the end effect, if desired (see 9.2.7),

3.1.13 Marking (see Section 21),

3.1.14 End use of pipe,

3.1.15 Special requirements,

3.1.16 Supplementary requirements, if any,

3.1.17 Selection of applicable level of preservation and packaging and level of packing required, if other than as specified or if MIL-STD-163 applies (see 22.1), and

3.1.18 Packaging and package marking, if desired (see 23.1).

4. Materials and Manufacture

4.1 The steel for both seamless and welded pipe shall be made by one or more of the following processes: open-hearth, electric-furnace, or basic-oxygen.

4.2 If steels of different grades are sequentially strand cast, identification of the resultant transition material is required. The steel producer shall remove the transition material by any established procedure that positively separates the grades.

4.3 The weld seam of electric-resistance welded pipe in Grade B shall be heat treated after welding to a minimum of 1000 °F [540 °C] so that no untempered martensite remains, or otherwise processed in such a manner that no untempered martensite remains.

4.4 When pipe is cold expanded, the amount of expansion shall not exceed 1½ % of the specified outside diameter of the pipe.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition given in Table 1 and the chemical

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

[6] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098

[7] Available from General Services Administration, Washington, DC 20405.

[8] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://api-ec.api.org.

TABLE 1 Chemical Requirements

	Composition, max, %								
	Carbon	Manganese	Phosphorus	Sulfur	Copper[A]	Nickel[A]	Chromium[A]	Molybdenum[A]	Vanadium[A]
Type S (seamless pipe)									
Grade A	0.25	0.95	0.05	0.045	0.40	0.40	0.40	0.15	0.08
Grade B	0.30	1.20	0.05	0.045	0.40	0.40	0.40	0.15	0.08
Type E (electric-resistance-welded)									
Grade A	0.25	0.95	0.05	0.045	0.50	0.40	0.40	0.15	0.08
Grade B	0.30	1.20	0.05	0.045	0.50	0.40	0.40	0.15	0.08
Type F (furnace-welded pipe)									
Grade A	0.30	1.20	0.05	0.045	0.40	0.40	0.40	0.15	0.08

[A] The total composition for these five elements shall not exceed 1.00 %.

analysis shall be in accordance with Test Methods, Practices, and Terminology A 751.

6. Product Analysis

6.1 The purchaser is permitted to perform an analysis of two pipes from each lot of 500 lengths, or fraction thereof. Samples for chemical analysis, except for spectrographic analysis, shall be taken in accordance with Practice E 1806. The chemical composition thus determined shall conform to the requirements given in Table 1.

6.2 If the analysis of either pipe does not conform to the requirements given in Table 1, analyses shall be made on additional pipes of double the original number from the same lot, each of which shall conform to the specified requirements.

7. Mechanical Properties

7.1 *Tension Test*:

7.1.1 For tension tests other than transverse weld tension tests, the yield strength corresponding to a permanent offset of 0.2 % of the gage length or to an extension of 0.5 % of the gage length under load, the tensile strength, and the elongation in 2 in. or 50 mm shall be determined, and the tension test results shall conform to the applicable tensile property requirements given in Table 2.

7.1.2 For transverse weld tension tests, the tensile strength shall be determined, and the tension test results shall conform to the applicable tensile strength requirement given in Table 2.

7.1.3 Electric-resistance-welded pipe NPS 8 [DN 200] or larger shall be tested using two transverse test specimens, one taken across the weld and one taken opposite the weld.

7.1.4 Transverse tension test specimens shall be approximately 1½ in. [38 mm] wide in the gage length and shall represent the full wall thickness of the pipe from which the test specimens were cut.

7.2 *Bend Test*:

7.2.1 For pipe NPS 2 [DN 50] or smaller, a sufficient length of pipe shall be capable of being bent cold through 90° around a cylindrical mandrel, the diameter of which is twelve times the specified outside diameter of the pipe, without developing cracks at any portion and without opening the weld.

TABLE 2 Tensile Requirements

	Grade A	Grade B
Tensile strength, min, psi [MPa]	48 000 [330]	60 000 [415]
Yield strength, min, psi [MPa]	30 000 [205]	35 000 [240]
Elongation in 2 in. or 50 mm	A,B	A,B

[A] The minimum elongation in 2 in. [50 mm] shall be that determined by the following equation:

$$e = 625\ 000\ [1940]\ A^{0.2}/U^{0.9}$$

where:

e = minimum elongation in 2 in. or 50 mm in percent, rounded to the nearest percent,

A = the lesser of 0.75 in.^{2} [500 mm^2] and the cross-sectional area of the tension test specimen, calculated using the specified outside diameter of the pipe, or the nominal width of the tension test specimen and the specified wall thickness of the pipe, with the calculated value rounded to the nearest 0.01 in.^{2} [1 mm^2], and

U = specified minimum tensile strength, psi [MPa].

[B] See Table X4.1 or Table X4.2, whichever is applicable, for the minimum elongation values that are required for various combinations of tension test specimen size and specified minimum tensile strength.

7.2.2 If ordered for close coiling, the pipe shall stand being bent cold through 180° around a cylindrical mandrel, the diameter of which is eight times the specified outside diameter of the pipe, without failure.

7.2.3 Double-extra-strong pipe over NPS 1¼ [DN 32] need not be subjected to the bend test.

7.3 *Flattening Test*:

7.3.1 The flattening test shall be made on welded pipe over NPS 2 [DN 50] in extra-strong weight or lighter.

7.3.2 *Seamless Pipe*:

7.3.2.1 Although testing is not required, pipe shall be capable of meeting the flattening test requirements of Supplementary Requirement S1, if tested.

7.3.3 *Electric-Resistance-Welded Pipe*:

7.3.3.1 A test specimen at least 4 in. [100 mm] in length shall be flattened cold between parallel plates in three steps, with the weld located either 0° or 90° from the line of direction of force as required by 7.3.3.2 or 7.3.3.3, whichever is applicable. During the first step, which is a test for ductility of the weld, except as allowed by 7.3.5, 7.3.6, and 7.3.7, no cracks or breaks on the inside or outside surface at the weld shall be present before the distance between the plates is less than two thirds of the specified outside diameter of the pipe. As a second step, the flattening shall be continued as a test for ductility away from the weld. During the second step, except as allowed by 7.3.6 and 7.3.7, no cracks or breaks on the inside or outside surface away from the weld shall be present before the distance between the plates is less than one third of the specified outside diameter of the pipe but is not less than five times the specified wall thickness of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the test specimen breaks or the opposite walls of the test specimen meet. Evidence of laminated or unsound material or of incomplete weld that is revealed by the flattening test shall be cause for rejection.

7.3.3.2 For pipe produced in single lengths, the flattening test specified in 7.3.3.1 shall be made using a test specimen taken from each end of each length of pipe. The tests from each end shall be made alternately with the weld at 0° and at 90° from the line of direction of force.

7.3.3.3 For pipe produced in multiple lengths, the flattening test specified in 7.3.3.1 shall be made as follows:

(1) Test specimens taken from, and representative of, the front end of the first pipe intended to be supplied from each coil, the back end of the last pipe intended to be supplied from each coil, and each side of any intermediate weld stop location shall be flattened with the weld located at 90° from the line of direction of force.

(2) Test specimens taken from pipe at any two locations intermediate to the front end of the first pipe and the back end of the last pipe intended to be supplied from each coil shall be flattened with the weld located at 0° from the line of direction of force.

7.3.3.4 For pipe that is to be subsequently reheated throughout its cross section and hot formed by a reducing process, the manufacturer shall have the option of obtaining the flattening test specimens required by 7.3.3.2 or 7.3.3.3, whichever is applicable, either prior to or after such hot reducing.

7.3.4 *Continuous-Welded Pipe*—A test specimen at least 4 in. [100 mm] in length shall be flattened cold between parallel plates in three steps. The weld shall be located at 90° from the line of direction of force. During the first step, which is a test for ductility of the weld, except as allowed by 7.3.5, 7.3.6, and 7.3.7, no cracks or breaks on the inside, outside, or end surfaces at the weld shall be present before the distance between the plates is less than three fourths of the specified outside diameter of the pipe. As a second step, the flattening shall be continued as a test for ductility away from the weld. During the second step, except as allowed by 7.3.6 and 7.3.7, no cracks or breaks on the inside, outside, or end surfaces away from the weld shall be present before the distance between the plates is less than 60 % of the specified outside diameter of the pipe. During the third step, which is a test for soundness, the flattening shall be continued until the test specimen breaks or the opposite walls of the test specimen meet. Evidence of laminated or unsound material or of incomplete weld that is revealed by the flattening test shall be cause for rejection.

7.3.5 Surface imperfections in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements in Section 12.

7.3.6 Superficial ruptures as a result of surface imperfections shall not be cause for rejection.

7.3.7 For pipe with a *D*-to-*t* ratio less than 10, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at such locations shall not be cause for rejection.

8. Hydrostatic Test

8.1 The hydrostatic test shall be applied, without leakage through the weld seam or the pipe body.

8.2 Plain-end pipe shall be hydrostatically tested to the applicable pressure given in Table X2.2, and threaded-and-coupled pipe shall be hydrostatically tested to the applicable pressure given in Table X2.3. It shall be permissible, at the discretion of the manufacturer, to perform the hydrostatic test on pipe with plain ends, with threads only, or with threads and couplings; and it shall also be permissible to test pipe in either single lengths or multiple lengths.

NOTE 4—The hydrostatic test pressures given herein are inspection test pressures, are not intended as a basis for design, and do not have any direct relationship to working pressures.

8.3 The minimum hydrostatic test pressure required to satisfy the requirements specified in 8.2 need not exceed 2500 psi [17 200 kPa] for pipe NPS 3 [DN 80] or smaller, or 2800 psi [19 300 kPa] for pipe larger than NPS 3 [DN 80]; however, the manufacturer has the option of using higher test pressures. For all sizes of seamless pipe and electric-resistance-welded pipe, the hydrostatic test pressure shall be maintained for at least 5 s.

9. Nondestructive Electric Test

9.1 *Type E Pipe*:

9.1.1 Except for pipe produced on a hot-stretch reducing mill, the weld seam of each length of electric-resistance-welded pipe NPS 2 [DN 50] or larger shall be tested with a nondestructive electric test in accordance with Practices E 213, E 273, E 309, or E 570. Each length of electric-resistance-welded pipe NPS 2 [DN 50] or larger and produced on a hot-stretch-reducing mill shall be tested with a nondestructive electric test that inpsects the full volume of the pipe in accordance with Practices E 213, E 309, or E 570.

9.1.2 *Ultrasonic and Electromagnetic Inspection*—Any equipment utilizing the ultrasonic or electromagnetic principles and capable of continuous and uninterrupted inspection of the weld seam shall be used. The equipment shall be checked with an applicable reference standard as described in 9.1.3 at least once every working turn or not more than 8 h to demonstrate its effectiveness and the inspection procedures. The equipment shall be adjusted to produce well-defined indications when the reference standard is scanned by the inspection unit in a manner simulating the inspection of the product.

9.1.3 *Reference Standards*—The length of the reference standards shall be determined by the pipe manufacturer, and they shall have the same specified diameter and thickness as the product being inspected. Reference standards shall contain machined notches, one on the inside surface and one on the outside surface, or a drilled hole, as shown in Fig. 1, at the option of the pipe manufacturer. The notches shall be parallel to the weld seam, and shall be separated by a distance sufficient to produce two separate and distinguishable signals. The ⅛-in. [3.2-mm] hole shall be drilled through the wall and perpendicular to the surface of the reference standard as shown in Fig. 1. Care shall be taken in the preparation of the reference standard to ensure freedom from fins or other edge roughness, or distortion of the pipe.

NOTE 5—The calibration standards shown in Fig. 1 are convenient standards for calibration of nondestructive testing equipment. The dimensions of such standards are not to be construed as the minimum sizes of imperfections detectable by such equipment.

9.1.4 *Acceptance Limits*—Table 3 gives the height of acceptance limit signals in percent of the height of signals produced by reference standards. Imperfections in the weld seam that produce a signal greater than the acceptance limit signal given in Table 3 shall be considered a defect unless the pipe manufacturer can demonstrate that the imperfection does not reduce the effective wall thickness beyond 12.5 % of the specified wall thickness.

9.2 *Type S Pipe*—As an alternative to the hydrostatic test at the option of the manufacturer or if specified in the purchase order, the full body of each seamless pipe shall be tested with a nondestructive electric test in accordance with Practice E 213, E 309, or E 570. In such cases, each length so furnished shall include the mandatory marking of the letters "NDE." Except as allowed by 9.2.6.2, it is the intent of this nondestructive electric test to reject pipe with imperfections that produce test signals equal to or greater than those produced by the applicable calibration standards.

9.2.1 If the nondestructive electric test has been performed, the lengths shall be marked with the letters "NDE." The certification, if required, shall state Nondestructive Electric Tested and shall indicate which of the tests was applied. Also, the letters NDE shall be appended to the product specification number and grade shown on the certification.

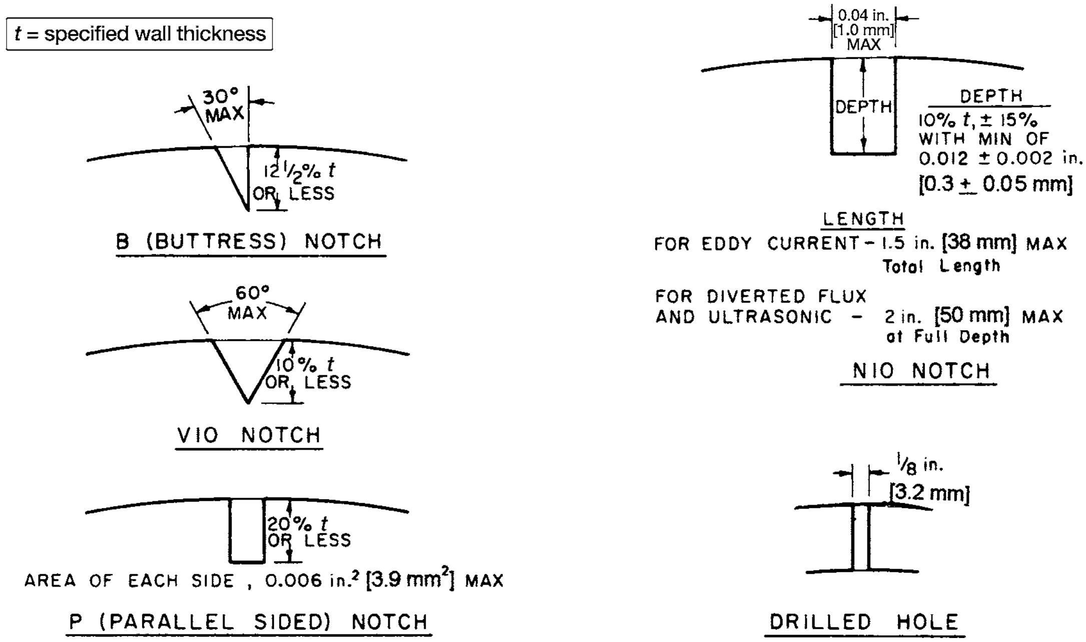

FIG. 1 Calibration Standards

TABLE 3 Acceptance Limits

Type Notch	Size of Hole		Acceptance Limit Signal, %
	in.	mm	
N10, V10	⅛	3.2	100
B, P	...	...	80

9.2.2 The following information is intended to facilitate the use of this specification:

9.2.2.1 The calibration standards defined in 9.2.3 through 9.2.5 are convenient standards for calibration of nondestructive testing equipment. The dimensions of such standards are not to be construed as the minimum sizes of imperfections detectable by such equipment.

9.2.2.2 The ultrasonic testing referred to in this specification is capable of detecting the presence and location of significant longitudinally or circumferentially oriented imperfections; however, different techniques need to be employed for the detection of differently oriented imperfections. Ultrasonic testing is not necessarily capable of detecting short, deep imperfections.

9.2.2.3 The eddy current examination referenced in this specification has the capability of detecting significant discontinuities, especially of the short abrupt type.

9.2.2.4 The flux leakage examination referred to in this specification is capable of detecting the presence and location of significant longitudinally or transversely oriented discontinuities. The provisions of this specification only require longitudinal calibration for flux leakage. Different techniques need to be employed for the detection of differently oriented imperfections.

9.2.2.5 The hydrostatic test referred to in 8.2 has the capability of finding imperfections of a size permitting the test fluid to leak through the tube wall and may be either visually seen or detected by a loss of pressure. Hydrostatic testing is not necessarily capable of detecting very tight through-the-wall imperfections or imperfections that extend an appreciable distance into the wall without complete penetration.

9.2.2.6 A purchaser interested in ascertaining the nature (type, size, location, and orientation) of imperfections that are capable of being detected in the specific application of these examinations is directed to discuss this with the manufacturer of the tubular product.

9.2.3 For ultrasonic testing, the calibration reference notches shall be at the option of the manufacturer, and shall be any one of the three common notch shapes shown in Practice E 213. The depth of notch shall not exceed 12.5 % of the specified wall thickness of the pipe or 0.004 in. [0.1 mm], whichever is the greater.

9.2.4 For eddy current testing, the calibration pipe shall contain, at the option of the manufacturer, any one of the following calibration standards to establish a minimum sensitivity level for rejection.

9.2.4.1 *Drilled Hole*—The calibration pipe shall contain three holes spaced 120° apart or four holes spaced 90° apart, sufficiently separated longitudinally to ensure separately distinguishable responses. The holes shall be drilled radially and completely through the pipe wall, care being taken to avoid distortion of the pipe while drilling. Dependent upon the nominal pipe size, the calibration pipe shall contain the following hole:

NPS	DN	Diameter of Drilled Hole
≤ ½	≤ 15	0.039 in. [1.0 mm]
> ½ ≤ 1¼	> 15 ≤ 32	0.055 in. [1.4 mm]
> 1¼ ≤ 2	> 32 ≤ 50	0.071 in. [1.8 mm]
> 2 ≤ 5	> 50 ≤ 125	0.087 in. [2.2 mm]
> 5	> 125	0.106 in. [2.7 mm]

9.2.4.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼ in. [6 mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the pipe. The notch shall have a depth not exceeding 12.5 % of the specified wall thickness of the pipe or 0.012 in. [0.3 mm], whichever is the greater.

9.2.4.3 *Longitudinal Notch*—A notch 0.031 in. [0.8 mm] or less in width shall be machined in a radial plane parallel to the pipe axis on the outside surface of the pipe, to a depth not exceeding 12.5 % of the specified wall thickness of the pipe or 0.012 in. [0.3 mm], whichever is the greater. The length of the notch shall be compatible with the testing method.

9.2.4.4 *Compatibility*—The calibration standards in the calibration pipe shall be compatible with the testing equipment and the method being used.

9.2.5 For flux leakage testing, the longitudinal calibration reference notches shall be straight-sided notches machined in a radial plane parallel to the pipe axis. For specified wall thicknesses less than 0.500 in. [12.7 mm], outside and inside notches shall be used. For specified wall thicknesses equal to or greater than 0.500 in. [12.7 mm], only an outside notch shall be used. The notch depth shall not exceed 12.5 % of the specified wall thickness, or 0.012 in. [0.3 mm], whichever is the greater. The notch length shall not exceed 1 in. [25 mm], and the notch width shall not exceed the notch depth. Outside diameter and inside diameter notches shall be located sufficiently apart to allow separation and identification of the signals.

9.2.6 Pipe containing one or more imperfections that produce a signal equal to or greater than the signal produced by the calibration standard shall be rejected or the area producing the signal shall be rejected.

9.2.6.1 Test signals produced by imperfections that cannot be identified, or produced by cracks or crack-like imperfections, shall result in rejection of the pipe, unless it is repaired and retested. To be accepted, the pipe shall pass the same specification test to which it was originally subjected and the remaining wall thickness shall not have been decreased below that permitted by the specification. It shall be permissible to reduce the outside diameter at the point of grinding by the amount so removed.

9.2.6.2 It shall be permissible to evaluate test signals produced by visual imperfections in accordance with the provisions of Section 12. A few examples of such imperfections are straightener marks, cutting chips, scratches, steel die stamps, stop marks, or pipe reducer ripple.

9.2.7 The test methods described in Section 9 are not necessarily capable of inspecting the end portion of pipes. This condition is referred to as end effect. The length of the end effect shall be determined by the manufacturer and, if specified in the purchase order, reported to the purchaser.

10. Permissible Variations in Weight (Mass) and Dimensions

10.1 *Weight (Mass)*—The weight (mass) of the pipe shall not vary more than ± 10 % from its specified weight (mass), as derived by multiplying its measured length by its specified weight (mass) per unit length, as given in Table X2.2 or Table X2.3, or as calculated using the relevant equation in ASME B36.10M.

NOTE 6—For pipe NPS 4 [DN 100] or smaller, the weight (mass) tolerance is applicable to the weights (masses) of the customary lifts of pipe as produced for shipment by the mill. For pipe larger than NPS 4 [DN 100], where individual lengths are weighed, the weight (mass) tolerance is applicable to the individual lengths.

10.2 *Diameter*—For pipe NPS 1½ [DN 40] or smaller, the outside diameter at any point shall not vary more than ± 1⁄64 in. [0.4 mm] from the specified outside diameter. For pipe NPS 2 [DN 50] or larger, the outside diameter shall not vary more than ± 1 % from the specified outside diameter.

10.3 *Thickness*—The minimum wall thickness at any point shall be not more than 12.5 % under the specified wall thickness. The minimum wall thickness on inspection shall conform to the requirements given in Table X2.4.

11. End Finish

11.1 If ordered with plain ends, the pipe shall be furnished to the following practice, unless otherwise specified.

11.1.1 *NPS 1½ [DN 40] or Smaller*—Unless otherwise specified in the purchase order, end finish shall be at the option of the manufacturer.

11.1.2 *Larger than NPS 1½ [DN 40]*:

11.1.2.1 Pipe of standard-weight or extra-strong weight, or in wall thickness less than 0.500 in. [12.7 mm], other than double extra-strong weight pipe, shall be plain-end beveled with ends beveled to an angle of 30°, +5°, -0°, measured from a line drawn perpendicular to the axis of the pipe, and with a root face of 1⁄16 in. ± 1⁄32 in. [1.6 mm ± 0.8 mm].

11.1.2.2 Pipe with a specified wall thickness greater than 0.500 in. [12.7 mm], and all double extra-strong weight pipe, shall be plain-end square cut.

11.2 If ordered with threaded ends, the pipe ends shall be provided with a thread in accordance with the gaging practice and tolerances of ANSI B1.20.1. For standard-weight pipe NPS 6 [DN 150] or smaller, refer to Table X3.1 for threading data. For standard-weight pipe NPS 8 [DN 200] or larger and all sizes of extra-strong weight pipe and double extra-strong weight pipe, refer to Table X3.2 for threading data. Threaded pipe NPS 4 [DN 100] or larger shall have thread protectors on the ends not protected by a coupling.

11.3 If ordered with couplings, one end of each length of pipe shall be provided with a coupling manufactured in accordance with Specification A 865. The coupling threads shall be in accordance with the gaging practice of ANSI B1.20.1. The coupling shall be applied handling-tight, unless power-tight is specified in the purchase order. Couplings are to be made of steel. Taper-tapped couplings shall be furnished on all threaded pipe NPS 2½ [DN 65] or larger. For pipe smaller than NPS 2½ [DN 65], it is regular practice to furnish straight-tapped couplings for standard-weight pipe and taper-tapped couplings for extra-strong and double extra-strong weight pipe. If taper-tapped couplings are required for standard-weight pipe smaller than NPS 2½ [DN 65], it is recommended that line pipe threads in accordance with API Specification 5B be ordered. The taper-tapped couplings provided on line pipe in such sizes may be used on mill-threaded standard-weight pipe of the same size.

12. Workmanship, Finish, and Appearance

12.1 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.

12.2 Surface imperfections that penetrate more than 12.5 % of the specified wall thickness or encroach on the minimum wall thickness shall be considered defects. Pipe with defects shall be given one or more of the following dispositions:

12.2.1 The defect shall be removed by grinding, provided that the remaining wall thickness is within specified limits,

12.2.2 Type S pipe and the parent metal of Type E pipe, except within ½ in. [13 mm] of the fusion line of the electric-resistance-weld seam, are permitted to be repaired in accordance with the welding provisions of 12.5. Repair welding of Type F pipe and the weld seam of Type E pipe is prohibited.

12.2.3 The section of pipe containing the defect shall be cut off within the limits of requirement on length, or

12.2.4 Rejected.

12.3 At the purchaser's discretion, pipe shall be subjected to rejection if surface defects repaired in accordance with 12.2 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.

12.4 For the removal of imperfections and defects by grinding, a smooth curved surface shall be maintained, and the wall thickness shall not be decreased below that permitted by this specification. It shall be permissible to reduce the outside diameter at the point of grinding by the amount so removed.

12.4.1 Wall thickness measurements shall be made with a mechanical caliper or with a properly calibrated nondestructive testing device of appropriate accuracy. In the case of a dispute, the measurement determined by use of the mechanical caliper shall govern.

12.5 Weld repair shall only be permitted with the approval of the purchaser and in accordance with Specification A 530/A 530M.

12.6 The finished pipe shall be reasonably straight.

12.7 The pipe shall contain no dents greater than 10 % of the pipe diameter or ¼ in. [6 mm], whichever is smaller, measured as the gap between the lowest point of the dent and a prolongation of the original contour of the pipe. Cold-formed dents deeper than ⅛ in. [3 mm] shall be free of sharp-bottomed gouges; it shall be permissible to remove the gouges by grinding, provided that the remaining wall thickness is within specified limits. The length of the dent in any direction shall not exceed one half the specified outside diameter of the pipe.

13. Number of Tests

13.1 Except as required by 13.2, one of each of the tests specified in Section 7 shall be made on test specimens taken from one length of pipe from each lot of each pipe size. For continuous-welded pipe, each lot shall contain no more than 25 tons [23 Mg] of pipe for pipe sizes NPS 1½ [DN 40] and smaller, and no more than 50 tons [45 Mg] of pipe for pipe sizes larger than NPS 1½ [DN 40]. For seamless and electric-resistance-welded pipe, a lot shall contain no more than one heat, and at the option of the manufacturer shall contain no more than 500 lengths of pipe (as initially cut after the final pipe-forming operation, prior to any further cutting to the required ordered lengths) or 50 tons [45 Mg] of pipe.

13.2 The number of flattening tests for electric-resistance-welded pipe shall be in accordance with 7.3.3.2 or 7.3.3.3, whichever is applicable.

13.3 Except as allowed by 9.2, each length of pipe shall be subjected to the hydrostatic test (see Section 8).

14. Retests

14.1 Except for flattening tests of electric-resistance-welded pipe, if the results of a mechanical test for a lot fail to conform to the applicable requirements specified in Section 7, the lot shall be rejected unless tests of additional pipe from the affected lot of double the number originally tested are subsequently made and each such test conforms to the specified requirements. Only one retest of any lot will be permitted. Any individual length of pipe that conforms to the test requirements is acceptable. Any individual length of pipe that does not conform to the test requirements may be resubmitted for test and will be considered acceptable if tests taken from each pipe end conform to the specified requirements.

14.2 *Electric-Resistance-Welded Pipe Produced in Single Lengths*—If any flattening test result fails to conform to the requirements specified in 7.3.3, the affected single length shall be rejected unless the failed end is subsequently retested using the same weld orientation as the failed test and a satisfactory test result is obtained before the pipe's length is reduced by such testing to less than 80 % of its length after the initial cropping.

14.3 *Electric-Resistance-Welded Pipe Produced in Multiple Lengths*—If any flattening test result fails to conform to the requirements specified in 7.3.3, the affected multiple length shall be rejected or flattening tests shall be made using a test specimen taken from each end of each individual length in the failed multiple length. For each pipe end, such tests shall be made with the weld alternately at 0° and 90° from the line of direction of force. Individual lengths are considered acceptable if the test results for both pipe ends conform to the specified requirements.

15. Test Methods

15.1 The test specimens and the tests required by this specification shall conform to those described in the latest issue of Test Methods and Definitions A 370.

15.2 Each longitudinal tension test specimen shall be taken from a pipe end and shall not be flattened between the gage marks.

15.3 Test specimens for bend tests and flattening tests shall be taken from pipe. Test specimens for flattening tests shall be smooth on the ends and free from burrs.

15.4 Tests shall be conducted at room temperature.

16. Lengths

16.1 Unless otherwise specified, pipe lengths shall be in accordance with the following regular practices:

16.1.1 Except as allowed by 16.1.2 and 16.1.4, pipe lighter than extra-strong weight shall be in single-random lengths of 16 to 22 ft [4.88 to 6.71 m], with not more than 5 % of the total number of threaded lengths furnished being jointers (two pieces coupled together).

16.1.2 For plain-end pipe lighter than extra-strong weight, it shall be permissible for not more than 5 % of the total number of pipe to be in lengths of 12 to 16 ft [3.66 to 4.88 m].

16.1.3 Pipe of extra-strong weight or heavier shall be in random lengths of 12 to 22 ft [3.66 to 6.71 m], except that it shall be permissible for not more than 5 % of the total of pipe to be in lengths of 6 to 12 ft [1.83 to 3.66 m].

16.1.4 For extra-strong weight or lighter pipe ordered in double-random lengths, the minimum lengths shall be not less than 22 ft [6.71 m] and the minimum average length for the order shall be not less than 35 ft [10.67 m].

16.1.5 For pipe heavier than extra-strong weight ordered in lengths longer than single random, the lengths shall be as agreed upon between the manufacturer and the purchaser.

16.1.6 If pipe is furnished threaded and coupled, the length shall be measured to the outer face of the coupling.

17. Galvanized Pipe

17.1 Galvanized pipe ordered under this specification shall be coated with zinc inside and outside by the hot-dip process. The zinc used for the coating shall be any grade of zinc conforming to Specification B 6.

17.2 *Weight (Mass) per Unit Area of Coating*—The weight (mass) per unit area of zinc coating shall be not less than 1.8 oz/ft^2 [0.55 kg/m^2] as determined from the average results of the two specimens taken for test in the manner prescribed in 17.5 and not less than 1.6 oz/ft^2 [0.49 kg/m^2] for each of these specimens. The weight (mass) per unit area of coating, expressed in ounces per square foot [kilograms per square metre] shall be calculated by dividing the total weight (mass) of zinc, inside plus outside, by the total area, inside plus outside, of the surface coated. Each specimen shall have not less than 1.3 oz/ft^2 [0.40 kg/m^2] of zinc coating on each surface, calculated by dividing the total weight (mass) of zinc on the given surface (outside or inside) by the area of the surface coated (outside or inside).

17.3 *Weight (Mass) per Unit Area of Coating Test*—The weight (mass) per unit area of zinc coating shall be determined by stripping tests in accordance with Test Method A 90/A 90M.

17.4 *Test Specimens*—Test specimens for determination of weight (mass) per unit area of coating shall be cut approximately 4 in. [100 mm] in length.

17.5 *Number of Tests*—Two test specimens for the determination of weight (mass) per unit area of coating shall be taken, one from each end of one length of galvanized pipe selected at random from each lot of 500 lengths, or fraction thereof, of each size.

17.6 *Retests*—If the weight (mass) per unit area of coating of any lot does not conform to the requirements specified in 17.2, retests of two additional pipes from the same lot shall be made, each of which shall conform to the specified requirements.

17.7 If pipe ordered under this specification is to be galvanized, the tension, flattening, and bend tests shall be made on the base material before galvanizing, if practicable. If specified, results of the mechanical tests on the base material shall be reported to the purchaser. If it is impracticable to make the mechanical tests on the base material before galvanizing, it shall be permissible to make such tests on galvanized samples, and any flaking or cracking of the zinc coating shall not be considered cause for rejection. If galvanized pipe is bent or otherwise fabricated to a degree that causes the zinc coating to stretch or compress beyond the limit of elasticity, some flaking of the coating is acceptable.

18. Inspection

18.1 The inspector representing the purchaser shall have entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector all reasonable facilities to be satisfied that the pipe is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

19. Rejection

19.1 The purchaser is permitted to inspect each length of pipe received from the manufacturer and, if it does not meet the requirements of this specification based upon the inspection and test method as outlined in the specification, the length shall be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

19.2 Pipe found in fabrication or in installation to be unsuitable for the intended use, under the scope and requirements of this specification, shall be set aside and the manufacturer notified. Such pipe shall be subject to mutual investigation as to the nature and severity of the deficiency and the forming or installation, or both, conditions involved. Disposition shall be a matter for agreement.

20. Certification

20.1 The manufacturer or supplier shall, upon request, furnish to the purchaser a certificate of compliance stating that the material has been manufactured, sampled, tested, and inspected in accordance with this specification (including year-date), and has been found to meet the requirements.

20.2 *Test Report*—For Types E and S, the manufacturer or supplier shall furnish to the purchaser a chemical analysis report for the elements given in Table 1.

20.3 *EDI*—A certificate of compliance or test report printed from, or used in, electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The use and format of the EDI document are subject to agreement between the purchaser and the manufacturer or supplier.

NOTE 7—EDI is the computer to computer exchange of business information in a standard format such as ANSI ASC X12.

20.4 Notwithstanding the absence of a signature, the organization submitting the certificate of compliance or test report is responsible for its content.

21. Product Marking

21.1 Except as allowed by 21.5 and 21.6, each length of pipe shall be legibly marked in the following sequence to show:

21.1.1 Manufacturer's name or mark,

21.1.2 Specification number (year-date not required),

NOTE 8—Pipe that complies with multiple compatible specifications may be marked with the appropriate designation for each specification.

21.1.3 Size (NPS and weight class, schedule number, or specified wall thickness; or specified outside diameter and specified wall thickness),

21.1.4 Grade (A or B),

21.1.5 Type of pipe (F, E, or S),

21.1.6 Test pressure, seamless pipe only (if applicable, in accordance with Table 4),

21.1.7 Nondestructive electric test, seamless pipe only (if applicable, in accordance with Table 4),

21.2 Unless another marking format is specified in the purchase order, length shall be marked in feet and tenths of a foot, or metres to two decimal places, dependent upon the units to which the pipe was ordered. The location of such marking shall be at the option of the manufacturer.

21.3 Heat number, lot number, run number, or a combination thereof shall be marked at the option of the manufacturer, unless specific marking is specified in the purchase order. The location of such marking shall be at the option of the manufacturer.

21.4 Any additional information desired by the manufacturer or specified in the purchase order.

21.5 For pipe NPS 1½ [DN 40] and smaller that is bundled, it shall be permissible to mark the required information on a tag securely attached to each bundle.

21.6 If pipe sections are cut into shorter lengths by a processor for resale as pipe, the processor shall transfer the complete identification, including the name or brand of the manufacturer, to each unmarked cut length, or to metal tags securely attached to unmarked pipe bundled in accordance with the requirements of 21.5. The same material designation shall be included with the information transferred, and the processor's name, trademark, or brand shall be added.

21.7 *Bar Coding*—In addition to the requirements in 21.1, 21.5, and 21.6, bar coding is acceptable as a supplementary identification method. It is recommended that bar coding be consistent with the Automotive Industry Action Group (AIAG) standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

TABLE 4 Marking of Seamless Pipe

Hydro	NDE	Marking
Yes	No	Test pressure
No	Yes	NDE
Yes	Yes	Test Pressure/NDE

22. Government Procurement

22.1 If specified in the contract, the pipe shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for shipment of such pipe shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 or Federal Std. No. 183 if continuous marking is required, for military agencies.

22.2 *Inspection*—Unless otherwise specified in the contract, the manufacturer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract, the manufacturer shall use its own or any other suitable facilities for performing the inspection and test requirements specified herein, unless otherwise disapproved by the purchaser in the contract or purchase order. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where deemed necessary to ensure that the pipe conforms to the specified requirements.

23. Packaging and Package Marking

23.1 If specified in the purchase order, packaging, marking, and loading for shipment shall be in accordance with those procedures recommended by Practices A 700.

24. Keywords

24.1 black steel pipe; seamless steel pipe; steel pipe; welded steel pipe; zinc coated steel pipe

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified in the purchase order. The purchaser may specify a different frequency of test than is provided in the supplementary requirement. Subject to agreement between the purchaser and manufacturer, retest and retreatment provisions of these supplementary requirements may also be modified.

S1. Flattening Test, Seamless Pipe

S1.1 A test specimen at least 2½ in. [60 mm] in length shall be flattened cold between parallel plates in two steps. During the first step, which is a test for ductility, except as allowed by S1.3, S1.4, and S1.5, no cracks or breaks on the inside, outside, or end surfaces shall be present before the distance between the plates is less than the value of *H* calculated as follows:

$$H = (1 + e)t/(e + t/D)$$

where:
H = distance between flattening plates, in. [mm],
e = deformation per unit length (constant for a given grade of steel, 0.09 for Grade A, and 0.07 for Grade B),
t = specified wall thickness, in. [mm], and
D = specified outside diameter, in. [mm]

The *H* values have been calculated for standard-weight and extra-heavy weight pipe from NPS 2½ to NPS 24 [DN 65 to DN 600], inclusive, and are given in Table X2.1.

S1.2 During the second step, which is a test for soundness, the flattening shall be continued until the test specimen breaks or the opposite sides of the test specimen meet. Evidence of laminated or unsound material that is revealed during the entire flattening test shall be cause for rejection.

S1.3 Surface imperfections in the test specimen before flattening, but revealed during the first step of the flattening test, shall be judged in accordance with the finish requirements in Section 12.

S1.4 Superficial ruptures as a result of surface imperfections shall not be cause for rejection.

S1.5 For pipe with a *D*-to-*t* ratio less than 10, because the strain imposed due to geometry is unreasonably high on the inside surface at the 6 and 12 o'clock locations, cracks at such locations shall not be cause for rejection.

S1.6 One test shall be made on test specimens taken from one length of pipe from each lot of each pipe size. A lot shall contain no more than one heat, and at the option of the manufacturer shall contain no more than 500 lengths of pipe (as initially cut after the final pipe-forming operation, prior to any further cutting to the required ordered lengths) or 50 tons [45 Mg] of pipe.

S1.7 If the results of a test for a lot fail to conform to the applicable requirements, the lot shall be rejected unless tests of additional pipe from the affected lot of double the number originally tested are subsequently made and each such test conforms to the specified requirements. Only one retest of any lot will be permitted. Any individual length of pipe that conforms to the test requirements is acceptable. Any individual length of pipe that does not conform to the test requirements may be resubmitted for test and will be considered acceptable if tests taken from each pipe end conform to the specified requirements.

APPENDIXES

(Nonmandatory Information)

X1. DEFINITIONS OF TYPES OF PIPE

X1.1 *Type F, Furnace-Butt-Welded Pipe, Continuous-Welded Pipe*—Pipe produced in multiple lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt joint forge welded by the mechanical pressure developed in rolling the hot-formed skelp through a set of round pass welding rolls.

X1.2 *Type E, Electric-Resistance-Welded Pipe*—Pipe produced in single lengths, or in multiple lengths from coiled skelp and subsequently cut into individual lengths, having a longitudinal butt joint wherein coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which the pipe is a part, and by the application of pressure.

X1.3 *Type S, Seamless Pipe*—Pipe made without a welded seam. It is manufactured by hot working steel and, if necessary, by subsequently cold finishing the hot-worked tubular product to produce the desired shape, dimensions, and properties.

X2. TABLES FOR DIMENSIONAL AND CERTAIN MECHANICAL REQUIREMENTS

X2.1 Tables X2.1-X2.4 address dimensional and certain mechanical requirements.

TABLE X2.1 Calculated *H* Values for Seamless Pipe

NPS Designator	DN Designator	Specified Outside Diameter, in. [mm]	Specified Wall Thickness, in. [mm]	Distance, in. [mm], Between Plates "*H*" by Formula: $H = (1 + e)t/(e + t/D)$	
				Grade A	Grade B
2½	65	2.875 [73.0]	0.203 [5.16] 0.276 [7.01]	1.378 [35.0] 1.618 [41.1]	1.545 [39.2] 1.779 [45.2]
3	80	3.500 [88.9]	0.216 [5.49] 0.300 [7.62]	1.552 [39.4] 1.861 [47.3]	1.755 [44.6] 2.062 [52.4]
3½	90	4.000 [101.6]	0.226 [5.74] 0.318 [8.08]	1.682 [42.7] 2.045 [51.9]	1.912 [48.6] 2.276 [57.8]
4	100	4.500 [114.3]	0.237 [6.02] 0.337 [8.56]	1.811 [46.0] 2.228 [56.6]	2.067 [52.5] 2.489 [63.2]
5	125	5.563 [141.3]	0.258 [6.55] 0.375 [9.52]	2.062 [52.4] 2.597 [66.0]	2.372 [60.2] 2.920 [74.2]
6	150	6.625 [168.3]	0.280 [7.11] 0.432 [10.97]	2.308 [58.6] 3.034 [77.1]	2.669 [67.8] 3.419 [86.8]
8	200	8.625 [219.1]	0.277 [7.04] 0.322 [8.18] 0.500 [12.70]	2.473 [62.8] 2.757 [70.0] 3.683 [93.5]	2.902 [73.7] 3.210 [81.5] 4.181 [106.2]
10	250	10.750 [273.0]	0.279 [7.09][A] 0.307 [7.80] 0.365 [9.27] 0.500 [12.70]	2.623 [66.6] 2.823 [71.7] 3.210 [81.5] 3.993 [101.4]	3.111 [79.0] 3.333 [84.7] 3.757 [95.4] 4.592 [116.6]
12	300	12.750 [323.8]	0.300 [7.62] 0.375 [9.52] 0.500 [12.70]	3.105 [78.9] 3.423 [86.9] 4.218 [107.1]	3.683 [93.5] 4.037 [102.5] 4.899 [124.4]
14	350	14.000 [355.6]	0.375 [9.52] 0.500 [12.70]	3.500 [88.9] 4.336 [110.1]	4.146 [105.3] 5.061 [128.5]
16	400	16.000 [406.4]	0.375 [9.52] 0.500 [12.70]	3.603 [91.5] 4.494 [114.1]	4.294 [109.1] 5.284 [134.2]
18	450	18.000 [457]	0.375 [9.52] 0.500 [12.70]	3.688 [93.7] 4.628 [117.6]	4.417 [112.2] 5.472 [139.0]
20	500	20.000 [508]	0.375 [9.52] 0.500 [12.70]	3.758 [95.5] 4.740 [120.4]	4.521 [114.8] 5.632 [143.1]
24	600	24.000 [610]	0.375 [9.52] 0.500 [12.70]	3.869 [98.3] 4.918 [124.9]	4.686 [119.0] 5.890 [149.6]

[A] Special order only.

TABLE X2.2 Dimensions, Weights (Masses) per Unit Length, and Test Pressures for Plain-End Pipe

NPS Designator	DN Designator	Specified Outside Diameter, in. [mm]	Specified Wall Thickness, in. [mm]	Nominal Weight (Mass) per Unit Length, Plain End, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure,[A] psi [kPa]	
							Grade A	Grade B
⅛	6	0.405 [10.3]	0.068 [1.73]	0.24 [0.37]	STD	40	700 [4800]	700 [4800]
			0.095 [2.41]	0.31 [0.47]	XS	80	850 [5900]	850 [5900]
¼	8	0.540 [13.7]	0.088 [2.24]	0.43 [0.63]	STD	40	700 [4800]	700 [4800]
			0.119 [3.02]	0.54 [0.80]	XS	80	850 [5900]	850 [5900]
⅜	10	0.675 [17.1]	0.091 [2.31]	0.57 [0.84]	STD	40	700 [4800]	700 [4800]
			0.126 [3.20]	0.74 [1.10]	XS	80	850 [5900]	850 [5900]
½	15	0.840 [21.3]	0.109 [2.77]	0.85 [1.27]	STD	40	700 [4800]	700 [4800]
			0.147 [3.73]	1.09 [1.62]	XS	80	850 [5900]	850 [5900]
			0.188 [4.78]	1.31 [1.95]	...	160	900 [6200]	900 [6200]
			0.294 [7.47]	1.72 [2.55]	XXS	...	1000 [6900]	1000 [6900]
¾	20	1.050 [26.7]	0.113 [2.87]	1.13 [1.69]	STD	40	700 [4800]	700 [4800]
			0.154 [3.91]	1.48 [2.20]	XS	80	850 [5900]	850 [5900]
			0.219 [5.56]	1.95 [2.90]	...	160	950 [6500]	950 [6500]
			0.308 [7.82]	2.44 [3.64]	XXS	...	1000 [6900]	1000 [6900]
1	25	1.315 [33.4]	0.133 [3.38]	1.68 [2.50]	STD	40	700 [4800]	700 [4800]
			0.179 [4.55]	2.17 [3.24]	XS	80	850 [5900]	850 [5900]
			0.250 [6.35]	2.85 [4.24]	...	160	950 [6500]	950 [6500]
			0.358 [9.09]	3.66 [5.45]	XXS	...	1000 [6900]	1000 [6900]
1¼	32	1.660 [42.2]	0.140 [3.56]	2.27 [3.39]	STD	40	1200 [8300]	1300 [9000]
			0.191 [4.85]	3.00 [4.47]	XS	80	1800 [12 400]	1900 [13 100]
			0.250 [6.35]	3.77 [5.61]	...	160	1900 [13 100]	2000 [13 800]
			0.382 [9.70]	5.22 [7.77]	XXS	...	2200 [15 200]	2300 [15 900]
1½	40	1.900 [48.3]	0.145 [3.68]	2.72 [4.05]	STD	40	1200 [8300]	1300 [9000]
			0.200 [5.08]	3.63 [5.41]	XS	80	1800 [12 400]	1900 [13 100]
			0.281 [7.14]	4.86 [7.25]	...	160	1950 [13 400]	2050 [14 100]
			0.400 [10.16]	6.41 [9.56]	XXS	...	2200 [15 200]	2300 [15 900]
2	50	2.375 [60.3]	0.154 [3.91]	3.66 [5.44]	STD	40	2300 [15 900]	2500 [17 200]
			0.218 [5.54]	5.03 [7.48]	XS	80	2500 [17 200]	2500 [17 200]
			0.344 [8.74]	7.47 [11.11]	...	160	2500 [17 200]	2500 [17 200]
			0.436 [11.07]	9.04 [13.44]	XXS	...	2500 [17 200]	2500 [17 200]
2½	65	2.875 [73.0]	0.203 [5.16]	5.80 [8.63]	STD	40	2500 [17 200]	2500 [17 200]
			0.276 [7.01]	7.67 [11.41]	XS	80	2500 [17 200]	2500 [17 200]
			0.375 [9.52]	10.02 [14.90]	...	160	2500 [17 200]	2500 [17 200]
			0.552 [14.02]	13.71 [20.39]	XXS	...	2500 [17 200]	2500 [17 200]
3	80	3.500 [88.9]	0.125 [3.18]	4.51 [6.72]	...	...	1290 [8900]	1500 [1000]
			0.156 [3.96]	5.58 [8.29]	...	...	1600 [11 000]	1870 [12 900]
			0.188 [4.78]	6.66 [9.92]	...	...	1930 [13 330]	2260 [15 600]
			0.216 [5.49]	7.58 [11.29]	STD	40	2220 [15 300]	2500 [17 200]
			0.250 [6.35]	8.69 [12.93]	...	...	2500 [17 200]	2500 [17 200]
			0.281 [7.14]	9.67 [14.40]	...	...	2500 [17 200]	2500 [17 200]
			0.300 [7.62]	10.26 [15.27]	XS	80	2500 [17 200]	2500 [17 200]
			0.438 [11.13]	14.34 [21.35]	...	160	2500 [17 200]	2500 [17 200]
			0.600 [15.24]	18.60 [27.68]	XXS	...	2500 [17 200]	2500 [17 200]
3½	90	4.000 [101.6]	0.125 [3.18]	5.18 [7.72]	...	...	1120 [7700]	1310 [19 000]
			0.156 [3.96]	6.41 [9.53]	...	...	1400 [6700]	1640 [11 300]
			0.188 [4.78]	7.66 [11.41]	...	...	1690 [11 700]	1970 [13 600]
			0.226 [5.74]	9.12 [13.57]	STD	40	2030 [14 000]	2370 [16 300]
			0.250 [6.35]	10.02 [14.92]	...	...	2250 [15 500]	2500 [17 200]
			0.281 [7.14]	11.17 [16.63]	...	...	2500 [17 200]	2500 [17 200]
			0.318 [8.08]	12.52 [18.63]	XS	80	2800 [19 300]	2800 [19 300]
4	100	4.500 [114.3]	0.125 [3.18]	5.85 [8.71]	...	...	1000 [6900]	1170 [8100]
			0.156 [3.96]	7.24 [10.78]	...	...	1250 [8600]	1460 [10 100]
			0.188 [4.78]	8.67 [12.91]	...	...	1500 [10 300]	1750 [12 100]
			0.219 [5.56]	10.02 [14.91]	...	...	1750 [12 100]	2040 [14 100]
			0.237 [6.02]	10.80 [16.07]	STD	40	1900 [13 100]	2210 [15 200]
			0.250 [6.35]	11.36 [16.90]	...	...	2000 [13 800]	2330 [16 100]
			0.281 [7.14]	12.67 [18.87]	...	...	2250 [15 100]	2620 [18 100]

TABLE X2.2 *Continued*

NPS Designator	DN Designator	Specified Outside Diameter, in. [mm]	Specified Wall Thickness, in. [mm]	Nominal Weight (Mass) per Unit Length, Plain End, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure,[A] psi [kPa]	
							Grade A	Grade B
			0.312 [7.92]	13.97 [20.78]	...	...	2500 [17 200]	2800 [19 300]
			0.337 [8.56]	15.00 [22.32]	XS	80	2700 [18 600]	2800 [19 300]
			0.438 [11.13]	19.02 [28.32]	...	120	2800 [19 300]	2800 [19 300]
			0.531 [13.49]	22.53 [33.54]	...	160	2800 [19 300]	2800 [19 300]
			0.674 [17.12]	27.57 [41.03]	XXS	...	2800 [19 300]	2800 [19 300]
5	125	5.563 [141.3]	0.156 [3.96]	9.02 [13.41]	...	...	1010 [7000]	1180 [8100]
			0.188 [4.78]	10.80 [16.09]	...	...	1220 [8400]	1420 [9800]
			0.219 [5.56]	12.51 [18.61]	...	...	1420 [9800]	1650 [11 400]
			0.258 [6.55]	14.63 [21.77]	STD	40	1670 [11 500]	1950 [13 400]
			0.281 [7.14]	15.87 [23.62]	...	...	1820 [12 500]	2120 [14 600]
			0.312 [7.92]	17.51 [26.05]	...	...	2020 [13 900]	2360 [16 300]
			0.344 [8.74]	19.19 [28.57]	...	...	2230 [15 400]	2600 [17 900]
			0.375 [9.52]	20.80 [30.94]	XS	80	2430 [16 800]	2800 [19 300]
			0.500 [12.70]	27.06 [40.28]	...	120	2800 [19 300]	2800 [19 300]
			0.625 [15.88]	32.99 [49.11]	...	160	2800 [19 300]	2800 [19 300]
			0.750 [19.05]	38.59 [57.43]	XXS	...	2800 [19 300]	2800 [19 300]
6	150	6.625 [168.3]	0.188 [4.78]	12.94 [19.27]	...	...	1020 [7000]	1190 [8200]
			0.219 [5.56]	15.00 [22.31]	...	...	1190 [8200]	1390 [9600]
			0.250 [6.35]	17.04 [25.36]	...	...	1360 [9400]	1580 [10 900]
			0.280 [7.11]	18.99 [28.26]	STD	40	1520 [10 500]	1780 [12 300]
			0.312 [7.92]	21.06 [31.32]	...	...	1700 [11 700]	1980 [13 700]
			0.344 [8.74]	23.10 [34.39]	...	...	1870 [12 900]	2180 [15 000]
			0.375 [9.52]	25.05 [37.28]	...	...	2040 [14 100]	2380 [16 400]
			0.432 [10.97]	28.60 [42.56]	XS	80	2350 [16 200]	2740 [18 900]
			0.562 [14.27]	36.43 [54.20]	...	120	2800 [19 300]	2800 [19 300]
			0.719 [18.26]	45.39 [67.56]	...	160	2800 [19 300]	2800 [19 300]
			0.864 [21.95]	53.21 [79.22]	XXS	...	2800 [19 300]	2800 [19 300]
8	200	8.625 [219.1]	0.188 [4.78]	16.96 [25.26]	...	...	780 [5400]	920 [6300]
			0.203 [5.16]	18.28 [27.22]	...	...	850 [5900]	1000 [6900]
			0.219 [5.56]	19.68 [29.28]	...	...	910 [6300]	1070 [7400]
			0.250 [6.35]	22.38 [33.31]	...	20	1040 [7200]	1220 [8400]
			0.277 [7.04]	24.72 [36.31]	...	30	1160 [7800]	1350 [9300]
			0.312 [7.92]	27.73 [41.24]	...	...	1300 [9000]	1520 [10 500]
			0.322 [8.18]	28.58 [42.55]	STD	40	1340 [9200]	1570 [10 800]
			0.344 [8.74]	30.45 [45.34]	...	...	1440 [9900]	1680 [11 600]
			0.375 [9.52]	33.07 [49.20]	...	...	1570 [10 800]	1830 [12 600]
			0.406 [10.31]	35.67 [53.08]	...	60	1700 [11 700]	2000 [13 800]
			0.438 [11.13]	38.33 [57.08]	...	...	1830 [12 600]	2130 [14 700]
			0.500 [12.70]	43.43 [64.64]	XS	80	2090 [14 400]	2430 [16 800]
			0.594 [15.09]	51.00 [75.92]	...	100	2500 [17 200]	2800 [19 300]
			0.719 [18.26]	60.77 [90.44]	...	120	2800 [19 300]	2800 [19 300]
			0.812 [20.62]	67.82 [100.92]	...	140	2800 [19 300]	2800 [19 300]
			0.875 [22.22]	72.49 [107.88]	XXS	...	2800 [19 300]	2800 [19 300]
			0.906 [23.01]	74.76 [111.27]	...	160	2800 [19 300]	2800 [19 300]
10	250	10.750 [273.0]	0.188 [4.78]	21.23 [31.62]	...	...	630 [4300]	730 [5000]
			0.203 [5.16]	22.89 [34.08]	...	...	680 [4700]	800 [5500]
			0.219 [5.56]	24.65 [36.67]	...	...	730 [5000]	860 [5900]
			0.250 [6.35]	28.06 [41.75]	...	20	840 [5800]	980 [6800]
			0.279 [7.09]	31.23 [46.49]	...	...	930 [6400]	1090 [7500]
			0.307 [7.80]	34.27 [51.01]	...	30	1030 [7100]	1200 [8300]
			0.344 [8.74]	38.27 [56.96]	...	...	1150 [7900]	1340 [9200]
			0.365 [9.27]	40.52 [60.29]	STD	40	1220 [8400]	1430 [9900]
			0.438 [11.13]	48.28 [71.87]	...	...	1470 [10 100]	1710 [11 800]
			0.500 [12.70]	54.79 [81.52]	XS	60	1670 [11 500]	1950 [13 400]
			0.594 [15.09]	64.49 [95.97]	...	80	1990 [13 700]	2320 [16 000]
			0.719 [18.26]	77.10 [114.70]	...	100	2410 [16 600]	2800 [19 300]
			0.844 [21.44]	89.38 [133.00]	...	120	2800 [19 300]	2800 [19 300]
			1.000 [25.40]	104.23 [155.09]	XXS	140	2800 [19 300]	2800 [19 300]
			1.125 [28.57]	115.75 [172.21]	...	160	2800 [19 300]	2800 [19 300]
12	300	12.750 [323.8]	0.203 [5.16]	27.23 [40.55]	...	...	570 [3900]	670 [4600]
			0.219 [5.56]	29.34 [43.63]	...	...	620 [4300]	720 [5000]
			0.250 [6.35]	33.41 [49.71]	...	20	710 [4900]	820 [5700]
			0.281 [7.14]	37.46 [55.75]	...	...	790 [5400]	930 [6400]
			0.312 [7.92]	41.48 [61.69]	...	...	880 [6100]	1030 [7100]
			0.330 [8.38]	43.81 [65.18]	...	30	930 [6400]	1090 [7500]

TABLE X2.2 *Continued*

NPS Designator	DN Designator	Specified Outside Diameter, in. [mm]	Specified Wall Thickness, in. [mm]	Nominal Weight (Mass) per Unit Length, Plain End, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure,[A] psi [kPa] Grade A	Grade B
			0.344 [8.74]	45.62 [67.90]	...	...	970 [6700]	1130 [7800]
			0.375 [9.52]	49.61 [73.78]	STD	...	1060 [7300]	1240 [8500]
			0.406 [10.31]	53.57 [79.70]	...	40	1150 [7900]	1340 [9200]
			0.438 [11.13]	57.65 [85.82]	...	...	1240 [8500]	1440 [9900]
			0.500 [12.70]	65.48 [97.43]	XS	...	1410 [9700]	1650 [11 400]
			0.562 [14.27]	73.22 [108.92]	...	60	1590 [11 000]	1850 [12 800]
			0.688 [17.48]	88.71 [132.04]	...	80	1940 [13 400]	2270 [15 700]
			0.844 [21.44]	107.42 [159.86]	...	100	2390 [16 500]	2780 [19 200]
			1.000 [25.40]	125.61 [186.91]	XXS	120	2800 [19 300]	2800 [19 300]
			1.125 [28.57]	139.81 [208.00]	...	140	2800 [19 300]	2800 [19 300]
			1.312 [33.32]	160.42 [238.68]	...	160	2800 [19 300]	2800 [19 300]
14	350	14.000 [355.6]	0.210 [5.33]	30.96 [46.04]	...	...	540 [3700]	630 [4300]
			0.219 [5.56]	32.26 [47.99]	...	...	560 [3900]	660 [4500]
			0.250 [6.35]	36.75 [54.69]	...	10	640 [4400]	750 [5200]
			0.281 [7.14]	41.21 [61.35]	...	...	720 [5000]	840 [5800]
			0.312 [7.92]	45.65 [67.90]	...	20	800 [5500]	940 [6500]
			0.344 [8.74]	50.22 [74.76]	...	...	880 [6100]	1030 [7100]
			0.375 [9.52]	54.62 [81.25]	STD	30	960 [6600]	1120 [7700]
			0.438 [11.13]	63.50 [94.55]	...	40	1130 [7800]	1310 [9000]
			0.469 [11.91]	67.84 [100.94]	...	...	1210 [8300]	1410 [9700]
			0.500 [12.70]	72.16 [107.39]	XS	...	1290 [8900]	1500 [10 300]
			0.594 [15.09]	85.13 [126.71]	...	60	1530 [10 500]	1790 [12 300]
			0.750 [19.05]	106.23 [158.10]	...	80	1930 [13 300]	2250 [15 500]
			0.938 [23.83]	130.98 [194.96]	...	100	2410 [16 600]	2800 [19 300]
			1.094 [27.79]	150.93 [224.65]	...	120	2800 [19 300]	2800 [19 300]
			1.250 [31.75]	170.37 [253.56]	...	140	2800 [19 300]	2800 [19 300]
			1.406 [35.71]	189.29 [281.70]	...	160	2800 [19 300]	2800 [19 300]
			2.000 [50.80]	256.56 [381.83]	...	...	2800 [19 300]	2800 [19 300]
			2.125 [53.97]	269.76 [401.44]	...	...	2800 [19 300]	2800 [19 300]
			2.200 [55.88]	277.51 [413.01]	...	...	2800 [19 300]	2800 [19 300]
			2.500 [63.50]	307.34 [457.40]	...	...	2800 [19 300]	2800 [19 300]
16	400	16.000 [406.4]	0.219 [5.56]	36.95 [54.96]	...	...	490 [3400]	570 [3900]
			0.250 [6.35]	42.09 [62.64]	...	10	560 [3900]	660 [4500]
			0.281 [7.14]	47.22 [70.30]	...	...	630 [4300]	740 [5100]
			0.312 [7.92]	52.32 [77.83]	...	20	700 [4800]	820 [5700]
			0.344 [8.74]	57.57 [85.71]	...	...	770 [5300]	900 [6200]
			0.375 [9.52]	62.64 [93.17]	STD	30	840 [5800]	980 [6800]
			0.438 [11.13]	72.86 [108.49]	...	...	990 [6800]	1150 [7900]
			0.469 [11.91]	77.87 [115.86]	...	...	1060 [7300]	1230 [8500]
			0.500 [12.70]	82.85 [123.30]	XS	40	1120 [7700]	1310 [9000]
			0.656 [16.66]	107.60 [160.12]	...	60	1480 [10 200]	1720 [11 900]
			0.844 [21.44]	136.74 [203.53]	...	80	1900 [13 100]	2220 [15 300]
			1.031 [26.19]	164.98 [245.56]	...	100	2320 [16 000]	2710 [18 700]
			1.219 [30.96]	192.61 [286.64]	...	120	2740 [18 900]	2800 [19 300]
			1.438 [36.53]	223.85 [333.19]	...	140	2800 [19 300]	2800 [19 300]
			1.594 [40.49]	245.48 [365.35]	...	160	2800 [19 300]	2800 [19 300]
18	450	18.000 [457]	0.250 [6.35]	47.44 [70.60]	...	10	500 [3400]	580 [4000]
			0.281 [7.14]	53.23 [79.24]	...	...	560 [3900]	660 [4500]
			0.312 [7.92]	58.99 [87.75]	...	20	620 [4300]	730 [5000]
			0.344 [8.74]	64.93 [96.66]	...	...	690 [4800]	800 [5500]
			0.375 [9.52]	70.65 [105.10]	STD	...	750 [5200]	880 [6100]
			0.406 [10.31]	76.36 [113.62]	...	...	810 [5600]	950 [6500]
			0.438 [11.13]	82.23 [122.43]	...	30	880 [6100]	1020 [7000]
			0.469 [11.91]	87.89 [130.78]	...	...	940 [6500]	1090 [7500]
			0.500 [12.70]	93.54 [139.20]	XS	...	1000 [6900]	1170 [8100]
			0.562 [14.27]	104.76 [155.87]	...	40	1120 [7700]	1310 [9000]
			0.750 [19.05]	138.30 [205.83]	...	60	1500 [10 300]	1750 [12 100]
			0.938 [23.83]	171.08 [254.67]	...	80	1880 [13 000]	2190 [15 100]
			1.156 [29.36]	208.15 [309.76]	...	100	2310 [15 900]	2700 [18 600]
			1.375 [34.92]	244.37 [363.64]	...	120	2750 [19 000]	2800 [19 300]
			1.562 [39.67]	274.48 [408.45]	...	140	2800 [19 300]	2800 [19 300]
			1.781 [45.24]	308.79 [459.59]	...	160	2800 [19 300]	2800 [19 300]
20	500	20.000 [508]	0.250 [6.35]	52.78 [78.55]	...	10	450 [3100]	520 [3600]
			0.281 [7.14]	59.23 [88.19]	...	...	510 [3500]	590 [4100]
			0.312 [7.92]	65.66 [97.67]	...	...	560 [3900]	660 [4500]
			0.344 [8.74]	72.28 [107.60]	...	...	620 [4300]	720 [5000]

TABLE X2.2 *Continued*

NPS Designator	DN Designator	Specified Outside Diameter, in. [mm]	Specified Wall Thickness, in. [mm]	Nominal Weight (Mass) per Unit Length, Plain End, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure,[A] psi [kPa]	
							Grade A	Grade B
			0.375 [9.52]	78.67 [117.02]	STD	20	680 [4700]	790 [5400]
			0.406 [10.31]	84.04 [126.53]	...	...	730 [5000]	850 [5900]
			0.438 [11.13]	91.59 [136.37]	...	...	790 [5400]	920 [6300]
			0.469 [11.91]	97.92 [145.70]	...	...	850 [5900]	950 [6500]
			0.500 [12.70]	104.23 [155.12]	XS	30	900 [6200]	1050 [7200]
			0.594 [15.09]	123.23 [183.42]	...	40	1170 [8100]	1250 [8600]
			0.812 [20.62]	166.56 [247.83]	...	60	1460 [10 100]	1710 [11 800]
			1.031 [26.19]	209.06 [311.17]	...	80	1860 [12 800]	2170 [15 000]
			1.281 [32.54]	256.34 [381.53]	...	100	2310 [15 900]	2690 [18 500]
			1.500 [38.10]	296.65 [441.49]	...	120	2700 [18 600]	2800 [19 300]
			1.750 [44.45]	341.41 [508.11]	...	140	2800 [19 300]	2800 [19 300]
			1.969 [50.01]	379.53 [564.81]	...	160	2800 [19 300]	2800 [19 300]
24	600	24.000 [610]	0.250 [6.35]	63.47 [94.46]	...	10	380 [2600]	440 [3000]
			0.281 [7.14]	71.25 [106.08]	...	...	420 [2900]	490 [3400]
			0.312 [7.92]	79.01 [117.51]	...	...	470 [3200]	550 [3800]
			0.344 [8.74]	86.99 [129.50]	...	...	520 [3600]	600 [4100]
			0.375 [9.52]	94.71 [140.88]	STD	20	560 [3900]	660 [4500]
			0.406 [10.31]	102.40 [152.37]	...	...	610 [4200]	710 [4900]
			0.438 [11.13]	110.32 [164.26]	...	...	660 [4500]	770 [5300]
			0.469 [11.91]	117.98 [175.54]	...	...	700 [4800]	820 [5700]
			0.500 [12.70]	125.61 [186.94]	XS	...	750 [5200]	880 [6100]
			0.562 [14.27]	140.81 [209.50]	...	30	840 [5800]	980 [6800]
			0.688 [17.48]	171.45 [255.24]	...	40	1030 [7100]	1200 [8300]
			0.938 [23.83]	231.25 [344.23]	...	...	1410 [9700]	1640 [11 300]
			0.969 [24.61]	238.57 [355.02]	...	60	1450 [10 000]	1700 [11 700]
			1.219 [30.96]	296.86 [441.78]	...	80	1830 [12 600]	2130 [14 700]
			1.531 [38.89]	367.74 [547.33]	...	100	2300 [15 900]	2680 [18 500]
			1.812 [46.02]	429.79 [639.58]	...	120	2720 [18 800]	2800 [19 300]
			2.062 [52.37]	483.57 [719.63]	...	140	2800 [19 300]	2800 [19 300]
			2.344 [59.54]	542.64 [807.63]	...	160	2800 [19 300]	2800 [19 300]
26	650	26.000 [660]	0.250 [6.35]	68.82 [102.42]	...	...	350 [2400]	400 [2800]
			0.281 [7.14]	77.26 [115.02]	...	...	390 [2700]	450 [3100]
			0.312 [7.92]	85.68 [127.43]	...	10	430 [3000]	500 [3400]
			0.344 [8.74]	94.35 [140.45]	...	...	480 [3300]	560 [3900]
			0.375 [9.52]	102.72 [152.80]	STD	...	520 [3600]	610 [4200]
			0.406 [10.31]	111.08 [165.28]	...	...	560 [3900]	660 [4500]
			0.438 [11.13]	119.69 [178.20]	...	...	610 [4200]	710 [4900]
			0.469 [11.91]	128.00 [190.46]	...	...	650 [4500]	760 [5200]
			0.500 [12.70]	136.30 [202.85]	XS	20	690 [4800]	810 [5600]
			0.562 [14.27]	152.83 [227.37]	...	...	780 [5400]	910 [6300]

[A] The minimum test pressure for outside diameters and wall thicknesses not listed shall be computed by the formula given below. The computed test pressure shall be used in all cases, except as follows:

(*1*) For specified wall thicknesses greater than the heaviest specified wall thickness listed in this table for the applicable specified outside diameter, the test pressure shall be the highest value listed for the applicable specified outside diameter and grade.

(*2*) For pipe smaller than NPS 2 [DN 50] with a specified wall thickness less than the lightest specified wall thickness listed in this table for the applicable specified outside diameter and grade.

(*3*) For all sizes of Grade A and B pipe smaller than NPS 2 [DN 50], the test pressures were assigned arbitrarily. Test pressures for intermediate specified outside diameters need not exceed those given in this table for the next larger listed size.

$$P = 2St/D$$

where:

P = minimum hydrostatic test pressure, psi [kPa],
S = 0.60 times the specified minimum yield strength, psi [kPa],
t = specified wall thickness, in. [mm], and
D = specified outside diameter, in. [mm].

TABLE X2.3 Dimensions, Weights (Masses) per Unit Length, and Test Pressures for Threaded and Coupled Pipe

NPS Designator	DN Designator	Specified Outside Diameter, in. [mm]	Specified Wall Thickness, in. [mm]	Nominal Weight (Mass) per Unit Length, Threaded and Coupled, lb/ft [kg/m]	Weight Class	Schedule No.	Test Pressure, psi [kPa]	
							Grade A	Grade B
1⁄8	6	0.405 [10.3]	0.068 [1.73]	0.25 [0.37]	STD	40	700 [4800]	700 [4800]
			0.095 [2.41]	0.32 [0.46]	XS	80	850 [5900]	850 [5900]
1⁄4	8	0.540 [13.7]	0.088 [2.24]	0.43 [0.63]	STD	40	700 [4800]	700 [4800]
			0.119 [3.02]	0.54 [0.80]	XS	80	850 [5900]	850 [5900]
3⁄8	10	0.675 [17.1]	0.091 [2.31]	0.57 [0.84]	STD	40	700 [4800]	700 [4800]
			0.126 [3.20]	0.74 [1.10]	XS	80	850 [5900]	850 [5900]
1⁄2	15	0.840 [21.3]	0.109 [2.77]	0.86 [1.27]	STD	40	700 [4800]	700 [4800]
			0.147 [3.73]	1.09 [1.62]	XS	80	850 [5900]	850 [5900]
			0.294 [7.47]	1.72 [2.54]	XXS	...	1000 [6900]	1000 [6900]
3⁄4	20	1.050 [26.7]	0.113 [2.87]	1.14 [1.69]	STD	40	700 [4800]	700 [4800]
			0.154 [3.91]	1.48 [2.21]	XS	80	850 [5900]	850 [5900]
			0.308 [7.82]	2.45 [3.64]	XXS	...	1000 [6900]	1000 [6900]
1	25	1.315 [33.4]	0.133 [3.38]	1.69 [2.50]	STD	40	700 [4800]	700 [4800]
			0.179 [4.55]	2.19 [3.25]	XS	80	850 [5900]	850 [5900]
			0.358 [9.09]	3.66 [5.45]	XXS	...	1000 [6900]	1000 [6900]
1 1⁄4	32	1.660 [42.2]	0.140 [3.56]	2.28 [3.40]	STD	40	1000 [6900]	1100 [7600]
			0.191 [4.85]	3.03 [4.49]	XS	80	1500 [10 300]	1600 [11 000]
			0.382 [9.70]	5.23 [7.76]	XXS	...	1800 [12 400]	1900 [13 100]
1 1⁄2	40	1.900 [48.3]	0.145 [3.68]	2.74 [4.04]	STD	40	1000 [6900]	1100 [7600]
			0.200 [5.08]	3.65 [5.39]	XS	80	1500 [10 300]	1600 [11 000]
			0.400 [10.16]	6.41 [9.56]	XXS	...	1800 [12 400]	1900 [13 100]
2	50	2.375 [60.3]	0.154 [3.91]	3.68 [5.46]	STD	40	2300 [15 900]	2500 [17 200]
			0.218 [5.54]	5.08 [7.55]	XS	80	2500 [17 200]	2500 [17 200]
			0.436 [11.07]	9.06 [13.44]	XXS	...	2500 [17 200]	2500 [17 200]
2 1⁄2	65	2.875 [73.0]	0.203 [5.16]	5.85 [8.67]	STD	40	2500 [17 200]	2500 [17 200]
			0.276 [7.01]	7.75 [11.52]	XS	80	2500 [17 200]	2500 [17 200]
			0.552 [14.02]	13.72 [20.39]	XXS	...	2500 [17 200]	2500 [17 200]
3	80	3.500 [88.9]	0.216 [5.49]	7.68 [11.35]	STD	40	2200 [15 200]	2500 [17 200]
			0.300 [7.62]	10.35 [15.39]	XS	80	2500 [17 200]	2500 [17 200]
			0.600 [15.24]	18.60 [27.66]	XXS	...	2500 [17 200]	2500 [17 200]
3 1⁄2	90	4.000 [101.6]	0.226 [5.74]	9.27 [13.71]	STD	40	2000 [13 800]	2400 [16 500]
			0.318 [8.08]	12.67 [18.82]	XS	80	2800 [19 300]	2800 [19 300]
4	100	4.500 [114.3]	0.237 [6.02]	10.92 [16.23]	STD	40	1900 [13 100]	2200 [15 200]
			0.337 [8.56]	15.20 [22.60]	XS	80	2700 [18 600]	2800 [19 300]
			0.674 [17.12]	27.62 [41.09]	XXS	...	2800 [19 300]	2800 [19 300]
5	125	5.563 [141.3]	0.258 [6.55]	14.90 [22.07]	STD	40	1700 [11 700]	1900 [13 100]
			0.375 [9.52]	21.04 [31.42]	XS	80	2400 [16 500]	2800 [19 300]
			0.750 [19.05]	38.63 [57.53]	XXS	...	2800 [19 300]	2800 [19 300]
6	150	6.625 [168.3]	0.280 [7.11]	19.34 [28.58]	STD	40	1500 [10 300]	1800 [12 400]
			0.432 [10.97]	28.88 [43.05]	XS	80	2300 [15 900]	2700 [18 600]
			0.864 [21.95]	53.19 [79.18]	XXS	...	2800 [19 300]	2800 [19 300]
8	200	8.625 [219.1]	0.277 [7.04]	25.53 [38.07]	...	30	1200 [8300]	1300 [9000]
			0.322 [8.18]	29.35 [43.73]	STD	40	1300 [9000]	1600 [11 000]
			0.500 [12.70]	44.00 [65.41]	XS	80	2100 [14 500]	2400 [16 500]
			0.875 [22.22]	72.69 [107.94]	XXS	...	2800 [19 300]	2800 [19 300]
10	250	10.750 [273.0]	0.279 [7.09]	32.33 [48.80]	...	...	950 [6500]	1100 [7600]
			0.307 [7.80]	35.33 [53.27]	...	30	1000 [6900]	1200 [8300]
			0.365 [9.27]	41.49 [63.36]	STD	40	1200 [8300]	1400 [9700]
			0.500 [12.70]	55.55 [83.17]	XS	60	1700 [11 700]	2000 [13 800]
12	300	12.750 [323.8]	0.330 [8.38]	45.47 [67.72]	...	30	950 [6500]	1100 [7600]
			0.375 [9.52]	51.28 [76.21]	STD	...	1100 [7600]	1200 [8300]
			0.500 [12.70]	66.91 [99.4]	XS	...	1400 [9700]	1600 [11 000]

TABLE X2.4 Table of Minimum Permissible Wall Thicknesses on Inspection for Pipe Specified Wall Thicknesses

NOTE 1—The following equation, upon which this table is based, shall be applied to calculate minimum permissible wall thickness from specified wall thickness:

$t_s \times 0.875 = t_m$

where:
t_s = specified wall thickness, in. [mm], and
t_m = minimum permissible wall thickness, in. [mm].
The wall thickness is expressed to three [two] decimal places, the fourth [third] decimal place being carried forward or dropped in accordance with Practice E 29.

NOTE 2—This table is a master table covering wall thicknesses available in the purchase of different classifications of pipe, but it is not meant to imply that all of the walls listed therein are obtainable under this specification.

Specified Wall Thickness (t_s), in. [mm]	Minimum Permissible Wall Thickness on Inspection (t_m), in. [mm]	Specified Wall Thickness (t_s), in. [mm]	Minimum Permissible Wall Thickness on Inspection (t_m), in. [mm]	Specified Wall Thickness (t_s), in. [mm]	Minimum Permissible Wall Thickness on Inspection (t_m), in. [mm]
0.068 [1.73]	0.060 [1.52]	0.294 [7.47]	0.257 [6.53]	0.750 [19.05]	0.656 [16.66]
0.088 [2.24]	0.077 [1.96]	0.300 [7.62]	0.262 [6.65]	0.812 [20.62]	0.710 [18.03]
0.091 [2.31]	0.080 [2.03]	0.307 [7.80]	0.269 [6.83]	0.844 [21.44]	0.739 [18.77]
0.095 [2.41]	0.083 [2.11]	0.308 [7.82]	0.270 [6.86]	0.864 [21.94]	0.756 [19.20]
0.109 [2.77]	0.095 [2.41]	0.312 [7.92]	0.273 [6.93]	0.875 [22.22]	0.766 [19.46]
0.113 [2.87]	0.099 [2.51]	0.318 [8.08]	0.278 [7.06]	0.906 [23.01]	0.793 [20.14]
0.119 [3.02]	0.104 [2.64]	0.322 [8.18]	0.282 [7.16)	0.938 [23.82]	0.821 [20.85]
0.125 [3.18]	0.109 [2.77)	0.330 [8.38]	0.289 [7.34]	0.968 [24.59]	0.847 [21.51]
0.126 [3.20]	0.110 [2.79]	0.337 [8.56]	0.295 [7.49]	1.000 [25.40]	0.875 [22.22]
0.133 [3.38]	0.116 [2.95]	0.343 [8.71]	0.300 [7.62]	1.031 [26.19]	0.902 [22.91]
0.140 [3.56]	0.122 [3.10]	0.344 [8.74]	0.301 [7.65]	1.062 [26.97]	0.929 [26.30]
0.145 [3.68]	0.127 [3.23]	0.358 [9.09]	0.313 [7.95]	1.094 [27.79]	0.957 [24.31]
0.147 [3.73]	0.129 [3.28]	0.365 [9.27]	0.319 [8.10]	1.125 [28.58]	0.984 [24.99]
0.154 [3.91]	0.135 [3.43]	0.375 [9.52]	0.328 [8.33]	1.156 [29.36]	1.012 [25.70]
0.156 [3.96]	0.136 [3.45]	0.382 [9.70]	0.334 [8.48]	1.219 [30.96]	1.067 [27.08]
0.179 [4.55]	0.157 [3.99]	0.400 [10.16]	0.350 [8.89]	1.250 [31.75]	1.094 [27.79]
0.187 [4.75]	0.164 [4.17]	0.406 [10.31]	0.355 [9.02]	1.281 [32.54]	1.121 [28.47]
0.188 [4.78]	0.164 [4.17]	0.432 [10.97]	0.378 [9.60]	1.312 [33.32]	1.148 [29.16]
0.191 [4.85]	0.167 [4.24]	0.436 [11.07]	0.382 [9.70]	1.343 [34.11]	1.175 [29.85]
0.200 [5.08]	0.175 [4.44]	0.437 [11.10]	0.382 [9.70]	1.375 [34.92]	1.203 [30.56]
0.203 [5.16]	0.178 [4.52]	0.438 [11.13]	0.383 [9.73]	1.406 [35.71]	1.230 [31.24]
0.216 [5.49]	0.189 [4.80]	0.500 [12.70]	0.438 [11.13]	1.438 [36.53]	1.258 [31.95]
0.218 [5.54]	0.191 [4.85]	0.531 [13.49]	0.465 [11.81]	1.500 [38.10]	1.312 [33.32]
0.219 [5.56]	0.192 [4.88]	0.552 [14.02]	0.483 [12.27]	1.531 [38.89]	1.340 [34.04]
0.226 [5.74]	0.198 [5.03]	0.562 [14.27]	0.492 [12.50]	1.562 [39.67]	1.367 [34.72]
0.237 [6.02]	0.207 [5.26]	0.594 [15.09]	0.520 [13.21]	1.594 [40.49]	1.395 [35.43]
0.250 [6.35]	0.219 [5.56]	0.600 [15.24]	0.525 [13.34]	1.750 [44.45]	1.531 [38.89]
0.258 [6.55]	0.226 [5.74]	0.625 [15.88]	0.547 [13.89]	1.781 [45.24]	1.558 [39.57]
0.276 [7.01]	0.242 [6.15]	0.656 [16.66]	0.574 [14.58]	1.812 [46.02]	1.586 [40.28]
0.277 [7.04]	0.242 [6.15]	0.674 [17.12]	0.590 [14.99]	1.968 [49.99]	1.722 [43.74]
0.279 [7.09]	0.244 [6.20]	0.688 [17.48]	0.602 [15.29]	2.062 [52.37]	1.804 [45.82]
0.280 [7.11]	0.245 [6.22]	0.719 [18.26]	0.629 [15.98]	2.344 [59.54]	2.051 [52.10]
0.281 [7.14]	0.246 [6.25]				

X3. BASIC THREADING DATA

X3.1 Fig. X3.1 is to be used with Table X3.1. Fig. X3.2 is to be used with Table X3.2.

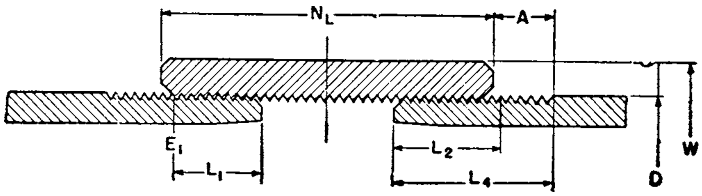

FIG. X3.1 Dimensions of Hand Tight Assembly for Use with Table X3.1

TABLE X3.1 Basic Threading Data for Standard-Weight Pipe, NPS 6 [DN 150] or Smaller

NOTE 1—All dimensions in this table are nominal and subject to mill tolerances.
NOTE 2—The taper of threads is ¾ in./ft [62.5 mm/m] on the diameter.

Pipe			Threads					Coupling		
NPS Designator	DN Designator	Specified Outside Diameter, in. [mm] D	Number per inch	End of Pipe to Hand Tight Plane, in. [mm] L_1	Effective Length, in. [mm] L_2	Total Length, in. [mm] L_4	Pitch Diameter at Hand Tight Plane, in. [mm] E_1	Specified Outside Diameter, in. [mm] W	Length, min., in. [mm] N_L	Hand Tight Stand-Off (Number of Threads) A
⅛	6	0.405 [10.3]	27	0.1615 [4.1021]	0.2638 [6.7005]	0.3924 [9.9670]	0.37360 [9.48944]	0.563 [14.3]	¾ [19]	4
¼	8	0.540 [13.7]	18	0.2278 [5.7861]	0.4018 [10.2057]	0.5946 [15.1028]	0.49163 [12.48740]	0.719 [18.3]	1⅛ [29]	5½
⅜	10	0.675 [17.1]	18	0.240 [6.096]	0.4078 [10.3581]	0.6006 [15.2552]	0.62701 [15.92605]	0.875 [22.2]	1⅛ [29]	5
½	15	0.840 [21.3]	14	0.320 [8.128]	0.5337 [13.5560]	0.7815 [19.8501]	0.77843 [19.77212]	1.063 [27.0]	1½ [38]	5
¾	20	1.050 [26.7]	14	0.339 [8.611]	0.5457 [13.8608]	0.7935 [20.1549]	0.98887 [25.11730]	1.313 [33.4]	1 9/16 [40]	5
1	25	1.315 [33.4]	11½	0.400 [10.160]	0.6828 [17.3431]	0.9845 [25.0063]	1.23863 [31.46120]	1.576 [40.0]	1 15/16 [49]	5
1¼	32	1.660 [42.2]	11½	0.420 [10.668]	0.7068 [17.9527]	1.0085 [25.6159]	1.58338 [40.21785]	1.900 [48.3]	2 [50]	5
1½	40	1.900 [48.3]	11½	0.420 [10.668]	0.7235 [18.3769]	1.0252 [26.0401]	1.82234 [46.28744]	2.200 [55.9]	2 [50]	5½
2	50	2.375 [60.3]	11½	0.436 [11.074]	0.7565 [19.2151]	1.0582 [26.8783]	2.29627 [58.32526]	2.750 [69.8]	2 1/16 [52]	5½
2½	65	2.875 [73.0]	8	0.682 [17.323]	1.1376 [28.8950]	1.5712 [39.9085]	2.76216 [70.15886]	3.250 [82.5]	3 1/16 [78]	5½
3	80	3.500 [88.9]	8	0.766 [19.456]	1.2000 [30.4800]	1.6337 [41.4960]	3.38850 [86.06790]	4.000 [101.6]	3 3/16 [81]	5½
3½	90	4.000 [101.6]	8	0.821 [20.853]	1.2500 [31.7500]	1.6837 [42.7660]	3.88881 [98.77577]	4.625 [117.5]	3 5/16 [84]	5½
4	100	4.500 [114.3]	8	0.844 [21.438]	1.3000 [33.0200]	1.7337 [44.0360]	4.38713 [111.43310]	5.000 [127.0]	3 7/16 [87]	5
5	125	5.563 [141.3]	8	0.937 [23.800]	1.4063 [35.7200]	1.8400 [46.7360]	5.44929 [138.41200]	6.296 [159.9]	3 11/16 [94]	5
6	150	6.625 [168.3]	8	0.958 [24.333]	1.5125 [38.4175]	1.9462 [49.4335]	6.50597 [165.25164]	7.390 [187.7]	3 15/16 [100]	6

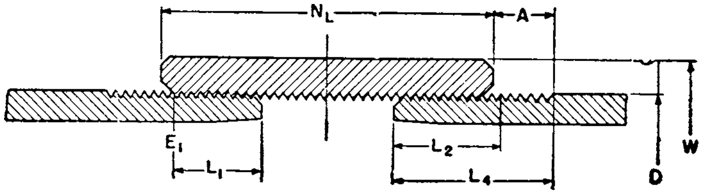

FIG. X3.2 Dimensions of Hand Tight Assembly for Use with Table X3.2

TABLE X3.2 Basic Threading Data for Standard-Weight Pipe, NPS 8 [DN 200] or Larger, and all Sizes of Extra-Strong and Double-Extra-Strong Weight Pipe

NOTE 1—The taper of threads is ¾ in./ft [62.5 mm/m] on the diameter.

Pipe				Threads										Coupling			
NPS Designator	DN Designator	Specified Outside Diameter, in. *D*	[mm]	Number per Inch	End of Pipe to Hand Tight Plane, in. L_1	[mm]	Effective Length, in. L_2	[mm]	Total Length, in. L_4	[mm]	Pitch Diameter at Hand Tight Plane, in. E_1	[mm]	Specified Outside Diameter, in. *W*	[mm]	Length, min, in. N_L	[mm]	Hand Tight Stand-Off (Number of Threads)
⅛	6	0.405	[10.3]	27	0.1615	[4.1021]	0.2638	[6.7005]	0.3924	[9.9670]	0.37360	[9.48944]	0.563	[14.3]	1¹⁄₁₆	[27]	3
¼	8	0.540	[13.7]	18	0.2278	[5.7861]	0.4018	[10.2057]	0.5946	[15.1028]	0.49163	[12.48740]	0.719	[18.3]	1⅝	[41]	3
⅜	10	0.675	[17.1]	18	0.240	[6.096]	0.4078	[10.3581]	0.6006	[15.2552]	0.62701	[15.92605]	0.875	[22.2]	1⅝	[41]	3
½	15	0.840	[21.3]	14	0.320	[8.128]	0.5337	[13.5560]	0.7815	[19.8501]	0.77843	[19.77212]	1.063	[27.0]	2⅛	[54]	3
¾	20	1.050	[26.7]	14½	0.339	[8.611]	0.5457	[13.8608]	0.7935	[20.1549]	0.98887	[25.11730]	1.313	[33.4]	2⅛	[54]	3
1	25	1.315	[33.4]	11	0.400	[10.160]	0.6828	[17.3431]	0.9845	[25.0063]	1.23863	[31.46120]	1.576	[40.0]	2⅝	[67]	3
1¼	32	1.660	[42.2]	11½	0.420	[10.668]	0.7068	[17.9527]	1.0085	[25.6159]	1.58338	[40.21785]	2.054	[52.2]	2¾	[70]	3
1½	40	1.900	[48.3]	11½	0.420	[10.668]	0.7235	[18.3769]	1.0252	[26.0401]	1.82234	[46.28744]	2.200	[55.9]	2¾	[70]	3
2	50	2.375	[60.3]	11½	0.436	[11.074]	0.7565	[19.2151]	1.0582	[26.8783]	2.29627	[58.32526]	2.875	[73.0]	2⅞	[73]	3
2½	65	2.875	[73.0]	8	0.682	[17.323]	1.1375	[28.8950]	1.5712	[39.9085]	2.76216	[70.15886]	3.375	[85.7]	4⅛	[105]	2
3	80	3.500	[88.9]	8	0.766	[19.456]	1.2000	[30.4800]	1.6337	[41.4960]	3.38850	[86.06790]	4.000	[101.6]	4¼	[108]	2
3½	90	4.000	[101.6]	8	0.821	[20.853]	1.2500	[31.7500]	1.6837	[42.7660]	3.88881	[98.77577]	4.625	[117.5]	4⅜	[111]	2
4	100	4.500	[114.3]	8	0.844	[21.438]	1.3000	[33.0200]	1.7337	[44.0360]	4.38713	[111.43310]	5.200	[132.1]	4½	[114]	2
5	125	5.563	[141.3]	8	0.937	[23.800]	1.4063	[35.7200]	1.8400	[46.7360]	5.44929	[138.41200]	6.296	[159.9]	4⅝	[117]	2
6	150	6.625	[168.3]	8	0.958	[24.333]	1.5125	[38.4175]	1.9462	[49.4335]	6.50597	[165.25164]	7.390	[187.7]	4⅞	[124]	2
8	200	8.625	[219.1]	8	1.063	[27.000]	1.7125	[43.4975]	2.1462	[54.5135]	8.50003	[215.90076]	9.625	[244.5]	5¼	[133]	2
10	250	10.750	[273.0]	8	1.210	[30.734]	1.9250	[48.8950]	2.3587	[59.9110]	10.62094	[269.77188]	11.750	[298.4]	5¾	[146]	2
12	300	12.750	[323.8]	8	1.360	[34.544]	2.1250	[53.9750]	2.5587	[64.9910]	12.61781	[320.49237]	14.000	[355.6]	6⅛	[156]	2
14	350	14.000	[355.6]	8	1.562	[39.675]	2.2500	[57.1500]	2.6837	[68.1660]	13.87263	[352.36480]	15.000	[381.0]	6⅜	[162]	2
16	400	16.000	[406.4]	8	1.812	[46.025]	2.4500	[62.2300]	2.8837	[73.2460]	15.87575	[403.24405]	17.000	[432]	6¾	[171]	2
18	450	18.000	[457]	8	2.000	[50.800]	2.6500	[67.3100]	3.0837	[78.3260]	17.87500	[454.02500]	19.000	[483]	7⅛	[181]	2
20	500	20.000	[508]	8	2.125	[53.975]	2.8500	[72.3900]	3.2837	[83.4060]	19.87031	[504.70587]	21.000	[533]	7⅝	[194]	2

X4. ELONGATION VALUES

X4.1 Tabulated in Table X4.1 are the minimum elongation values in inch-pound units, calculated using the equation given in Table 2.

TABLE X4.1 Elongation Values

Area, *A*, in.²	Specified Wall Thickness, in.			Elongation in 2 in., min, %	
	Tension Test Specimen			Specified Minimum Tensile Strength, psi	
	¾-in. Specimen	1-in. Specimen	1½-in. Specimen	48 000	60 000
0.75 and greater	0.994 and greater	0.746 and greater	0.497 and greater	36	30
0.74	0.980–0.993	0.735–0.745	0.490–0.496	36	29
0.73	0.967–0.979	0.726–0.734	0.484–0.489	36	29
0.72	0.954–0.966	0.715–0.725	0.477–0.483	36	29
0.71	0.941–0.953	0.706–0.714	0.471–0.476	36	29
0.70	0.927–0.940	0.695–0.705	0.464–0.470	36	29
0.69	0.914–0.926	0.686–0.694	0.457–0.463	36	29
0.68	0.900–0.913	0.675–0.685	0.450–0.456	35	29
0.67	0.887–0.899	0.666–0.674	0.444–0.449	35	29
0.66	0.874–0.886	0.655–0.665	0.437–0.443	35	29

TABLE X4.1 *Continued*

Area, *A*, in.^{2}	Specified Wall Thickness, in.			Elongation in 2 in., min, %	
	Tension Test Specimen			Specified Minimum Tensile Strength, psi	
	¾-in. Specimen	1-in. Specimen	1½-in. Specimen	48 000	60 000
0.65	0.861–0.873	0.646–0.654	0.431–0.436	35	29
0.64	0.847–0.860	0.635–0.645	0.424–0.430	35	29
0.63	0.834–0.846	0.626–0.634	0.417–0.423	35	29
0.62	0.820–0.833	0.615–0.625	0.410–0.416	35	28
0.61	0.807–0.819	0.606–0.614	0.404–0.409	35	28
0.60	0.794–0.806	0.595–0.605	0.397–0.403	35	28
0.59	0.781–0.793	0.586–0.594	0.391–0.396	34	28
0.58	0.767–0.780	0.575–0.585	0.384–0.390	34	28
0.57	0.754–0.766	0.566–0.574	0.377–0.383	34	28
0.56	0.740–0.753	0.555–0.565	0.370–0.376	34	28
0.55	0.727–0.739	0.546–0.554	0.364–0.369	34	28
0.54	0.714–0.726	0.535–0.545	0.357–0.363	34	28
0.53	0.701–0.713	0.526–0.534	0.351–0.356	34	28
0.52	0.687–0.700	0.515–0.525	0.344–0.350	34	27
0.51	0.674–0.686	0.506–0.514	0.337–0.343	33	27
0.50	0.660–0.673	0.495–0.505	0.330–0.336	33	27
0.49	0.647–0.659	0.486–0.494	0.324–0.329	33	27
0.48	0.634–0.646	0.475–0.485	0.317–0.323	33	27
0.47	0.621–0.633	0.466–0.474	0.311–0.316	33	27
0.46	0.607–0.620	0.455–0.465	0.304–0.310	33	27
0.45	0.594–0.606	0.446–0.454	0.297–0.303	33	27
0.44	0.580–0.593	0.435–0.445	0.290–0.296	32	27
0.43	0.567–0.579	0.426–0.434	0.284–0.289	32	26
0.42	0.554–0.566	0.415–0.425	0.277–0.283	32	26
0.41	0.541–0.553	0.406–0.414	0.271–0.276	32	26
0.40	0.527–0.540	0.395–0.405	0.264–0.270	32	26
0.39	0.514–0.526	0.386–0.394	0.257–0.263	32	26
0.38	0.500–0.513	0.375–0.385	0.250–0.256	32	26
0.37	0.487–0.499	0.366–0.374	0.244–0.249	31	26
0.36	0.474–0.486	0.355–0.365	0.237–0.243	31	26
0.35	0.461–0.473	0.346–0.354	0.231–0.236	31	25
0.34	0.447–0.460	0.335–0.345	0.224–0.230	31	25
0.33	0.434–0.446	0.326–0.334	0.217–0.223	31	25
0.32	0.420–0.433	0.315–0.325	0.210–0.216	30	25
0.31	0.407–0.419	0.306–0.314	0.204–0.209	30	25
0.30	0.394–0.406	0.295–0.305	0.197–0.203	30	25
0.29	0.381–0.393	0.286–0.294	0.191–0.196	30	24
0.28	0.367–0.380	0.275–0.285	0.184–0.190	30	24
0.27	0.354–0.366	0.266–0.274	0.177–0.183	29	24
0.26	0.340–0.353	0.255–0.265	0.170–0.176	29	24
0.25	0.327–0.339	0.246–0.254	0.164–0.169	29	24
0.24	0.314–0.326	0.235–0.245	0.157–0.163	29	24
0.23	0.301–0.313	0.226–0.234	0.151–0.156	29	23
0.22	0.287–0.300	0.215–0.225	0.144–0.150	28	23
0.21	0.274–0.286	0.260–0.214	0.137–0.143	28	23
0.20	0.260–0.273	0.195–0.205	0.130–0.136	28	23
0.19	0.247–0.259	0.186–0.194	0.124–0.129	27	22
0.18	0.234–0.246	0.175–0.185	0.117–0.123	27	22
0.17	0.221–0.233	0.166–0.174	0.111–0.116	27	22
0.16	0.207–0.220	0.155–0.165	0.104–0.110	27	22
0.15	0.194–0.206	0.146–0.154	0.097–0.103	26	21
0.14	0.180–0.193	0.135–0.145	0.091–0.096	26	21
0.13	0.167–0.179	0.126–0.134	0.084–0.090	25	21
0.12	0.154–0.166	0.115–0.125	0.077–0.083	25	20
0.11	0.141–0.153	0.106–0.114	0.071–0.076	25	20
0.10	0.127–0.140	0.095–0.105	0.064–0.070	24	20
0.09	0.114–0.126	0.086–0.094	0.057–0.063	24	19
0.08	0.100–0.113	0.075–0.085	0.050–0.056	23	19
0.07	0.087–0.099	0.066–0.074	0.044–0.049	22	18
0.06	0.074–0.086	0.055–0.065	0.037–0.043	22	18
0.05	0.061–0.073	0.046–0.054	0.031–0.036	21	17
0.04	0.047–0.060	0.035–0.045	0.024–0.030	20	16
0.03	0.034–0.046	0.026–0.034	0.017–0.023	19	16
0.02	0.020–0.033	0.015–0.025	0.010–0.016	17	14
0.01 and less	0.019 and less	0.014 and less	0.009 and less	15	12

X4.2 Tabulated in Table X4.2 are the minimum elongation values in SI units, calculated using the equation given in Table 2.

TABLE X4.2 Elongation Values

Area, A, mm^2	Specified Wall Thickness, mm			Elongation in 50 mm, min, %	
	Tension Test Specimen			Specified Minimum Tensile Strength, MPa	
	19-mm Specimen	25-mm Specimen	38-mm Specimen	330	415
500 and greater	26.3 and greater	20.0 and greater	13.2 and greater	36	30
480-499	25.3-26.2	19.2-19.9	12.7-13.1	36	30
460-479	24.2-25.2	18.4-19.1	12.1-12.6	36	29
440-459	23.2-24.1	17.6-18.3	11.6-12.0	36	29
420-439	22.1-23.1	16.8-17.5	11.1-11.5	35	29
400-419	21.1-22.0	16.0-16.7	10.6-11.0	35	29
380-399	20.0-21.0	15.2-15.9	10.0-10.5	35	28
360-379	19.0-19.9	14.4-15.0	9.5-9.9	34	28
340-359	17.9-18.9	13.6-14.3	9.0-9.4	34	28
320-339	16.9-17.8	12.8-13.5	8.5-8.9	34	27
300-319	15.8-16.8	12.0-12.7	7.9-8.4	33	27
280-299	14.8-15.7	11.2-11.9	7.4-7.8	33	27
260-279	13.7-14.7	10.4-11.1	6.9-7.3	32	26
240-259	12.7-13.6	9.6-10.3	6.4-6.8	32	26
220-239	11.6-12.6	8.8-9.5	5.8-6.3	31	26
200-219	10.5-11.5	8.0-8.7	5.3-5.7	31	25
190-199	10.0-10.4	7.6-7.9	5.0-5.2	30	25
180-189	9.5-9.9	7.2-7.5	4.8-4.9	30	24
170-179	9.0-9.4	6.8-7.1	4.5-4.7	30	24
160-169	8.4-8.9	6.4-6.7	4.2-4.4	29	24
150-159	7.9-8.3	6.0-6.3	4.0-4.1	29	24
140-149	7.4-7.8	5.6-5.9	3.7-3.9	29	23
130-139	6.9-7.3	5.2-5.5	3.5-3.6	28	23
120-129	6.3-6.8	4.8-5.1	3.2-3.4	28	23
110-119	5.8-6.2	4.4-4.7	2.9-3.1	27	22
100-109	5.3-5.7	4.0-4.3	2.7-2.8	27	22
90-99	4.8-5.2	3.6-3.9	2.4-2.6	26	21
80-89	4.2-4.7	3.2-3.5	2.1-2.3	26	21
70-79	3.7-4.1	2.8-3.1	1.9-2.0	25	21
60-69	3.2-3.6	2.4-2.7	1.6-1.8	24	20
50-59	2.7-3.1	2.0-2.3	...	24	19
40-49	2.1-2.6	1.6-1.9	...	23	19
30-39	1.6-2.0	...	...	22	18

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 53/A 53M – 06a, that may impact the use of this specification. (Approved September 1, 2007)

(*1*) Revised 9.1.1 to require the use of full-volumetric NDE on Type E pipe produced on a hot-stretch reducing mill.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 53/A 53M – 06, that may impact the use of this specification. (Approved October 1, 2006)

(*1*) Revised 1.1 to address supplementary requirements.
(*2*) Added new 3.1.16 and renumbered subsequent paragraphs.
(*3*) Revised 7.3.1.
(*4*) Revised 7.3.2.
(*5*) Deleted Note 4 and renumbered subsequent notes.
(*6*) Added Supplementary Requirement S1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 53/A 53M – 05, that may impact the use of this specification. (Approved May 1, 2006)

(*1*) Revised the minimum coupling length for NPS 6 in Table X3.1.

(*2*) Editorially corrected the minimum coupling length for NPS ¾ in Table X3.1 and the DN designation for NPS 6 in the title for Table X3.1.