



Designation: A790/A790M – 17

Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe¹

This standard is issued under the fixed designation A790/A790M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification² covers 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 SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the *M* designation of this specification is specified in the order.

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

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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-790 in Section II of that Code.

2. Referenced Documents

2.1 *ASTM Standards*:³

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A923 Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels

A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys

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

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E309 Practice for Eddy Current Examination of Steel Tubular Products Using Magnetic Saturation

E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings

E426 Practice for Electromagnetic (Eddy Current) Examination of Seamless and Welded Tubular Products, Titanium, Austenitic Stainless Steel and Similar Alloys

E527 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

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

2.5 AWS Standard:⁷

A5.9 Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Electrodes

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 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**),

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification refer to Terminology **A941**.

⁷ Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, <http://www.aws.org>.

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
S32202		1870–1975 [1020–1080]	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
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		1960–2085 [1070–1140]	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
S33207		1905–2085 [1040–1140]	Rapid cooling in water or by other means
S39274		1920–2060 [1025–1125]	Rapid cooling in air or water
S39277		1975–2155 [1080–1180]	Rapid cooling in air or water
S81921		1760–2010 [960–1100]	Rapid cooling in air or water
S82011		1850–2050 [1010–1120]	Rapid cooling in air or water
S82121		1830–2010 [1000–1100]	Rapid cooling in air or water
S82441		1870 [1020]	Rapid cooling in air or water
S83071	...	1830–2100 [1000–1150]	Rapid cooling in water or by other means

^ACommon name, not a trademark, widely used, not associated with any one producer. 329 is an AISI number.

4.1.7 End finish (section on ends of Specification **A999/A999M**),

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 **A999/A999M**),

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 **A999/A999M** 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 Unless otherwise stated in the order, all pipe shall be furnished in the heat-treated condition as shown in **Table 1**.

6.3.1 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.

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 from plate that has been heat treated as required by **Table 1** for the particular grade is required, *provided a sample of that heat of finished pipe or material representative of that heat of pipe as a prolongation of the weld passes the Test Methods **A923 Method B or C** (See **Note 2**), including base metal, weld metal, and heat affected zone per heat. Each pipe supplied under this requirement shall be stenciled with the suffix "HT-O."*

6.3.2.2 For materials not listed in **Table 3** of Test Methods **A923**, the HT-O provision does not apply.

NOTE 2—The Test Methods **A923** test method (B or C) is at the manufacturer's option, unless otherwise specified by the purchaser.

7. Chemical Composition

7.1 The steel shall conform to the chemical requirements as prescribed in **Table 2**.

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 $\frac{1}{8}$ to and including NPS 8 are available in a length up to 24 ft (see **Note 3**) with the permissible range of 15 to 24 ft (see **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 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 $\frac{1}{4}$ 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 **A999/A999M**.

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

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	...
S32202		0.030	2.00	0.040	0.010	1.00	1.00–2.80	21.5–24.0	0.45	0.18–0.26	...	...
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 ^D	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 ^E		0.030	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
S32808		0.030	1.10	0.030	0.010	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	...	...
S33207		0.030	1.50	0.035	0.010	0.80	6.0–9.0	29.0–33.0	3.0–5.0	0.40–0.60	1.0	...
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
S81921		0.030	2.00–4.00	0.040	0.030	1.00	2.00–4.00	19.0–22.0	1.00–2.00	0.14–0.20	...	...
S82011		0.030	2.0–3.0	0.040	0.020	1.00	1.00–2.00	20.5–23.5	0.10–1.00	0.15–0.27	0.50	...
S82121	...	0.035	1.00–2.50	0.040	0.010	1.00	2.00–4.00	21.0–23.0	0.30–1.30	0.15–0.25	0.20–1.20	...
S82441		0.030	2.5–4.0	0.035	0.005	0.70	3.0–4.5	23.0–25.0	1.00–2.00	0.20–0.30	0.10–0.80	...
S83071	...	0.030	0.50–1.50	0.030	0.020	0.50	6.0–8.0	29.0–31.0	3.0–4.0	0.28–0.40	0.80	...

^AMaximum, 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.

^BNew designation established in accordance with Practice E527 and SAE J 1086.

^CCommon name, not a trademark, widely used, not associated with any one producer. 329 is an AISI number.

^D% Cr + 3.3 × % Mo + 16 × % N ≥ 41.

^E% Cr + 3.3 × % Mo + 16 × % N ≥ 40.

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

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						
t ≤ 0.187 in. [5.00 mm]		100 [690]	70 [485]	25	290	30
t > 0.187 in. [5.00 mm]		95 [655]	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	...
S32202		94 [650]	65 [450]	30	290	30
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	310	32
S32808						
t < 0.40 in. [10 mm]		116 [800]	80 [550]	15	310	32
t ≥ 0.40 in. [10 mm]		101 [700]	72 [500]	15	310	32
S32900	329	90 [620]	70 [485]	20	271	28
S32906						
t < 0.40 in. [10 mm]		116 [800]	94 [650]	25	300	32
t ≥ 0.40 in. [10 mm]		109 [750]	80 [550]	25	300	32
S32950		100 [690]	70 [480]	20	290	30
S33207						
t < 0.157 in. [4 mm]		138 [950]	112 [770]	15	336	36
t ≥ 0.157 in. [4 mm]		123 [850]	101 [700]	15	336	36
S39274		116 [800]	80 [550]	15	310	32
S39277		120 [825]	90 [620]	25	290	30
S81921		90 [620]	65 [450]	25	290	30
S82011						
t < 0.187 in. [5.00 mm]		101 [700]	75 [515]	30	293	31
t ≥ 0.187 in. [5.00 mm]		95 [655]	65 [450]	30	293	31
S82121	...	94 [650]	65 [450]	25	286	30
S82441 t < 0.4 inches [10 mm]		107 [740]	78 [540]	25	290	...
S82441 t > 0.4 inches [10mm]		99 [680]	70 [480]	25	290	...
S83071	...	120 [830]	98 [680]	25	300	32

^ACommon name, not a trademark, widely used, not associated with any one producer. 329 is an AISI number.

^BPrior to A790/A790M – 04, the tensile strength value for UNS 32760 was 109–130 ksi [750–895 MPa].

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 **A370**. 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 **A999/A999M**, 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 **E213** or **E309**.

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 **E213** or **E309**. 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 **E426**) 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 **E213**, 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