Designation: A985/A985M – 18a

Standard Specification for Steel Investment Castings General Requirements, for Pressure-Containing Parts[1]

This standard is issued under the fixed designation A985/A985M; 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 are mandatory for steel castings produced by the investment casting process for pressure-containing parts under each of the following ASTM Specifications:

Title of Specification	ASTM Designation
Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service	A216/A216M
Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service	A217/A217M
Castings, Austenitic, for Pressure-Containing Parts	A351/A351M
Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service	A352/A352M
Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service	A389/A389M
Steel Castings Suitable for Pressure Service	A487/A487M
Castings, Iron-Nickel-Chromium and Nickel Alloys, Specially Controlled for Pressure-Retaining Parts for Corrosive Service	A990/A990M
Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts	A995/A995M

1.2 This specification also covers a group of supplementary requirements, which may be applied to the above specifications as indicated therein. These requirements are provided for use when additional testing or inspection is desired, and apply only when specified individually by the purchaser in the order.

1.3 When investment casting is ordered, the requirements of this specification shall take precedence over the individual material specification requirements.

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 shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A216/A216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service

A217/A217M Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service

A351/A351M Specification for Castings, Austenitic, for Pressure-Containing Parts

A352/A352M Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A380/A380M Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems

A389/A389M Specification for Steel Castings, Alloy, Specially Heat Treated, for Pressure-Containing Parts, Suitable for High-Temperature Service

A487/A487M Specification for Steel Castings Suitable for Pressure Service

A488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A609/A609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof

[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.

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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**

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A800/A800M Practice for Steel Casting, Austenitic Alloy, Estimating Ferrite Content Thereof
A903/A903M Specification for Steel Castings, Surface Acceptance Standards, Magnetic Particle and Liquid Penetrant Inspection
A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A967/A967M Specification for Chemical Passivation Treatments for Stainless Steel Parts
A990/A990M Specification for Castings, Iron-Nickel-Chromium and Nickel Alloys, Specially Controlled for Pressure-Retaining Parts for Corrosive Service
A991/A991M Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
A995/A995M Specification for Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts
A1058 Test Methods for Mechanical Testing of Steel Products—Metric
A1067/A1067M Specification for Test Coupons for Steel Castings
A1080 Practice for Hot Isostatic Pressing of Steel, Stainless Steel, and Related Alloy Castings
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E94/E94M Guide for Radiographic Examination Using Industrial Radiographic Film
E125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings
E165/E165M Practice for Liquid Penetrant Examination for General Industry
E186 Reference Radiographs for Heavy-Walled (2 to 4½ in. (50.8 to 114 mm)) Steel Castings
E192 Reference Radiographs of Investment Steel Castings for Aerospace Applications
E208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels
E280 Reference Radiographs for Heavy-Walled (4½ to 12 in. (114 to 305 mm)) Steel Castings
E340 Practice for Macroetching Metals and Alloys
E353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
E354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
E446 Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness
E709 Guide for Magnetic Particle Testing
E2660 Digital Reference Images for Investment Steel Castings for Aerospace Applications

2.2 *ANSI Standard:*[3]
B16.5 Pipe Flanges and Flanged Fittings

2.3 *ASME Standard:*[4]
ASME Boiler and Pressure Vessel Code, Section III, NB-2546

2.4 *Standards of the Manufacturers Standardization Society of the Valve and Fitting Industry:*[5]
MSS SP 53 Quality Standard for Steel Castings and Forgings for Valves, Flanges and Fittings and Other Piping Components (Magnetic Particle Exam Method)
MSS SP 54 Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components (Radiographic Examination Method)

2.5 *SAE Aerospace Recommended Practice:*[6]
ARP 1341 Determining Decarburization and Carburization in Finished Parts of Carbon and Low-Alloy Steels

3. Terminology

3.1 *Definitions*—The definitions in Test Methods and Definitions A370, Terminology A941, and Test Methods A1058 are applicable to this specification and to those listed in 1.1.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *heat, n*—all the molten metal poured from a single furnace, or all of the molten metal from two or more furnaces, poured into a single ladle or casting prior to the replenishing of the furnace(s).

3.2.2 *investment casting, n*—a metal casting that is produced in a mold obtained by investing (surrounding) an expendable pattern with a ceramic slurry, which is allowed to solidify. The expendable pattern may consist of wax, plastic, or other material, and is removed prior to filling the mold with liquid metal.

3.2.3 *master heat, n*—a single furnace charge of alloy that may be either poured directly into castings or into remelt alloy for individual melts.

3.2.4 *sub-heat, n*—a portion of master heat remelted with only minor additions for deoxidation for pouring into castings. Synonyms—*melt*, *production heat*.

4. Materials and Manufacture

4.1 When the purchaser imposes the requirements of this specification, the manufacturer is responsible for compliance with the specification requirements during the production and processing of the casting by themselves and any of their subcontractors.

4.2 *Melting Process*—Master heats shall be made by the electric furnace process, with or without separate refining such as argon-oxygen-decarburization (AOD), vacuum-oxygen-degassing (VOD), vacuum-induction-melting (VIM), and so forth, unless otherwise specified in the individual specification or agreed upon between the customer and producer. Master

[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 of Mechanical Engineers (ASME), ASME International Headquarters, Two 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.

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

heats may be used directly for producing castings or converted into ingot, bar, shot, or other suitable form, not including gates and risers from casting production, for later remelting as a sub-heat.

4.3 *Re-Melting Process*—Sub-heats shall be produced from master heat metal in suitable batch sizes by electric induction furnace, with or without atmosphere protection such as vacuum or inert gas, unless otherwise agreed upon between the customer and producer. Revert (gates, sprues, risers, and rejected castings) shall not be remelted except in master heats.

4.4 *Heat Treatment:*

4.4.1 Ferritic and martensitic steel shall be cooled after pouring to provide substantially complete transformation of austenite prior to heat treatment to enhance mechanical properties.

4.4.2 Castings shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A991/A991M.

4.4.2.1 When castings are heat treated at temperatures above 2000 °F [1100 °C], then the working zone shall have been established by a survey performed at not more than 25 °F [15 °C] below nor more than 200 °F [110 °C] above the minimum heat treatment temperature specified for the grade. If a minimum heat treatment temperature is not specified for the grade, then the survey temperature shall be not more than 50 °F [30 °C] below nor more than 175 °F [100 °C] above the furnace set point used.

4.4.2.2 The maximum variation in measured temperature, as determined by the difference between the highest temperature and the lowest temperature, shall be as agreed between the purchaser and producer, except that during production heat treatment no portion of the furnace shall be below the minimum specified temperature nor above the maximum specified temperature for the grade being processed.

4.5 *Sampling:*

4.5.1 If castings are poured directly from one or more master heats, then the samples for chemical and other required testing also shall be poured directly from each of the master heats.

4.5.2 If castings are poured from a sub-heat, then the samples for chemical and other required testing also shall be poured from a sub-heat of that same master heat, but not necessarily from the same sub-heat as the castings. The sub-heat used for the test samples shall be produced using the same melting practices and additions as used to produce the castings.

4.5.3 Test specimens may be taken from castings or from coupons cast either integrally with the castings, in the same molds as the castings, or in separate molds.

4.5.4 Separately cast coupons for other than chemical analysis shall be cast in molds of the same material as those used for the castings, as shown in Specification A1067/A1067M, Figs. 1–4, except when Supplementary Requirement S26 is specified. The test coupon in Specification A1067/A1067M, Fig. 4 shall be employed only for austenitic alloy castings with cross sections less than 2½ in. [65 mm].[7]

4.5.5 Coupons for chemical analysis may be chill cast.

5. Chemical Composition

5.1 *Chemical Analysis*—Chemical analysis of materials covered by this specification shall be in accordance with Test Methods, Practices, and Terminology A751.

5.2 *Heat Analysis*—An analysis of samples obtained in accordance with 4.5 or Supplementary Requirement S29, as appropriate, shall be made by the manufacturer to determine the percentages of the elements specified for the grade being poured. When drillings are used, they shall be taken not less than 1/16 in. [1.6 mm] beneath the surface. The chemical composition thus determined shall be reported to the purchaser, or their representative, and shall conform to the requirements in the individual specification for the grade being poured.

5.3 *Product Analysis*—A product analysis may be made by the purchaser from material representing each master heat, sub-heat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis shall be taken no closer than 1/16 in. [1.6 mm] to a cast surface, except that castings too thin for this shall be analyzed on representative material. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved, or shall be subject to rejection by the purchaser, except that the chemical composition determined for carbon and low-alloy steel castings may vary from the specified limits by the amounts shown in Table 1. The product analysis tolerances of Table 1 are not applicable as acceptance criteria for heat analysis by the casting manufacturer. When comparing product and heat analysis for other than carbon and low-alloy steels, the reproducibility data R2 in Test Methods E353 or E354, as applicable, shall be taken into consideration.

5.4 *Unspecified Elements*—When chemical analysis for elements not specified for the grade ordered is desired, Supplementary Requirement S1 may be specified.

NOTE 1—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 often is determined routinely by the producer.

5.5 *Grade Substitution*—Grade substitution is not permitted. Grade substitution occurs when the material being supplied contains one or more elements that are not specified for the supplied material such that the material conforms to the requirements of a different grade.

6. Mechanical Test Methods

6.1 All mechanical tests shall be conducted in accordance with Test Methods and Definitions A370, or when material is ordered to an M-suffix (SI units) standard, then in accordance with Test Methods A1058.

[7] Information on the relationship of mechanical properties determined on test coupons obtained as specified in 4.5.4 with those obtained from the casting may be found in *The Steel Castings Handbook, Fifth Edition*, Steel Founders' Society of America, 1980, pp. 15–35 through 15–43.

TABLE 1 Product Analysis Tolerances for Carbon and Low-Alloy Steels

Element	Range[A]	Tolerances[B, C] over max or under min, Limit, %
Carbon (C)	up to 0.65 %	0.03 × % C_L + 0.02
	above 0.65 %	0.04 %
Manganese (Mn)	up to 1 %	0.08 × % Mn_L + 0.01
	above 1 %	0.09
Silicon (Si)	up to 0.60 %	0.22 × % Si_L - 0.01
	above 0.60 %	0.15 %
Phosphorus (P)	all	0.13 × % P_L + 0.005
Sulfur (S)	all	0.36 × % S_L + 0.001
Nickel (Ni)	up to 2 %	0.10 × % Ni_L + 0.003
	above 2 %	0.25 %
Chromium (Cr)	up to 2 %	0.07 × % Cr_L + 0.04
	above 2 %	0.18 %
Molybdenum (Mo)	up to 0.6 %	0.04 × % Mo_L + 0.03
	above 0.6 %	0.06 %
Vanadium (V)	up to 0.25 %	0.23 × % V_L + 0.004
	above 0.25 %	0.06 %
Tungsten (W)	up to 0.10 %	0.08 × % W_L + 0.02
	above 0.10 %	0.02 %
Copper (Cu)	up to 0.15 %	0.18 × % Cu_L + 0.02
	above 0.15 %	0.05 %
Aluminum (Al)	up to 0.10 %	0.08 × % Al_L + 0.02
	above 0.10 %	0.03 %

[A] The range denotes the composition limits up to which the tolerances are computed by the equation, and above which the tolerances are given by a constant.

[B] The subscript $_L$ for the elements in each equation indicates that the limits of the element specified by the applicable specification are to be inserted into the equation to calculate the tolerance for the upper limit and the lower limit, if applicable, respectively. Examples of computing tolerances are presented in footnote C.

[C] To compute the tolerances, consider the manganese limits 0.50 – 80 % of Grade WC4 of Specification A217/A217M. According to Table 1, the maximum permissible deviation of a product analysis below the lower limit 0.50 is 0.05 % = (0.08 × 0.50 + 0.01). The lowest acceptable product analysis of Grade WC4, therefore, is 0.45 %. Similarly, the maximum permissible deviation above the upper limit of 0.80 % is 0.074 % = (0.08 × 0.08 + 0.01). The highest acceptable product analysis of Grade WC4, therefore is 0.874. For Grade WCC of Specification A216/A216M, the maximum manganese content is 1.40 % if the carbon content is 0.20 %. In this case, the highest acceptable product analysis is 1.49 = (1.40 + 0.09).

7. Tensile Requirements

7.1 Sampling for tension testing shall be in accordance with 4.5 or with Supplementary Requirement S30, as appropriate.

7.2 The coupon from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents.

7.3 To determine accordance with the tension test requirements, an observed value or calculated value shall be rounded off in accordance with Practice E29 to the nearest 0.5 ksi [5 MPa] for yield and tensile strength and to the nearest 1 % for elongation and reduction of area. 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 E29 would cause rejection of material.

8. Repair by Welding

8.1 Repair by welding shall be in accordance with the requirements of individual specifications using procedures and welders qualified in accordance with Practice A488/A488M.

9. Flanges

9.1 When a flange from a flanged casting is removed to make a weld-end casting, discontinuities may be observed that would not have been detrimental in a flanged casting. The disposition of the casting shall be subject to agreement between the purchaser and manufacturer.

10. Quality

10.1 The surface of the casting shall be free of adhering ceramic, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

10.2 The castings shall not be peened, plugged, or impregnated.

10.3 When additional inspection is desired, Supplementary Requirement S4, S5, S6, or S7 may be specified.

11. Hydrostatic Tests

11.1 Each casting shall be tested after machining to the hydrostatic shell test pressures prescribed in ANSI B16.5 for the applicable steel rating for which the casting is designed. The casting shall not show any leaks. Castings ordered for working pressures other than those in the standard ANSI ratings, or those listed for which test pressures are not specified by ANSI B16.5, shall be tested at a pressure agreed upon between the manufacturer and purchaser.

11.2 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 or machining has been performed on the casting. Castings ordered in the rough state for final machining by the purchaser may be tested hydrostatically prior to shipment by the manufacturer at pressures to be agreed upon with the purchaser. The foundry, however, is responsible for the satisfactory performance of the casting under the final test required in 11.1.

12. Workmanship, Finish, and Appearance

12.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser. When 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, unless otherwise agreed upon.

12.2 Machined welding ends shall be suitably protected against damage during shipping.

13. Retests

13.1 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.

13.2 If the results of the mechanical tests do not conform to the requirements specified, at the manufacturer's option, castings may be reheat treated and retested. Testing after reheat

treatment shall consist of the full number of specimens taken from locations complying with the specification or order.

NOTE 2—Test Methods and Definitions A370, paragraph 4.4, and Test Methods A1058, paragraph 3.5, address retesting because of mechanical reasons such as failure of the test equipment. Test Methods and Definitions A370, paragraph 14.4.2, addresses retesting for reasons such as fracture outside of the middle half of the gauge length or at a punch mark.

14. Inspection

14.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections, with the exception of product analysis (5.3), are the responsibility of the manufacturer.

15. Rejection and Rehearing

15.1 Any rejection based on test reports shall be reported to the manufacturer within 30 days from the receipt of the test reports by the purchaser.

15.2 Material that shows unacceptable discontinuities, as determined by the acceptance standards specified in the order subsequent to its acceptance at the manufacturer's works, will be rejected and the manufacturer shall be notified within 30 days after discovery of the rejectable condition.

15.3 Samples that represent rejected material shall be preserved for two 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.

16. Certification

16.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification (including year of issue) and was found to meet the requirements. When the purchaser imposes the requirements of this specification, the manufacturer is responsible for compliance with the specification requirements during the production and processing of the casting by themselves and any of their subcontractors.

16.2 As applicable, the certification also shall include:

16.2.1 Material specification and grade,

16.2.2 Pattern or part number,

16.2.3 Master heat number or serial number traceable to the master heat number,

16.2.4 Chemical analysis results required by the specification and supplementary requirements specified in the purchase order,

16.2.5 Mechanical property results required by the specification and supplementary requirements specified in the purchase order,

16.2.6 Statement of satisfactory inspection, visual, and nondestructive testing specified in the purchase order,

16.2.7 Manufacturer's name, and

16.2.8 Additional purchase order requirements.

16.3 A signature is not required on the certification; however, the document shall clearly identify the organization submitting the certification. Notwithstanding the absence of a signature, the organization submitting the certification is responsible for its content.

17. Product Marking

17.1 Castings shall be marked for material identification with the grade symbols (WCB, WC9, CF8M, and so forth). In addition, master heat numbers, or serial numbers that are traceable to master heat numbers, shall be marked on all pressure-containing casting individually weighing 50 lb [25 kg] or more. Pressure-containing castings weighing less than 50 lb [25 kg] shall be marked with either the master heat number or a lot number that will identify the casting as to the month in which it was poured. Marking shall be in such position so as not to injure the usefulness of the casting.

17.2 On castings for which impact property requirements are specified, stamped markings using low-stress stamps shall be on a raised pad when such pad can be made a part of the castings.

17.3 Castings shall be marked with the manufacturer's identification or symbols, except when other provisions have been made between the manufacturer and purchaser.

18. Keywords

18.1 castings; investment castings; master heat; pressure containing; steel castings; sub-heat

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. Unspecified Elements

S1.1 Limits may be established for elements not specified for the grade ordered by agreement between the manufacturer and purchaser. The results of the analysis for the agreed-upon elements shall be reported.

S2. Destruction Tests

S2.1 Purchaser may select representative castings from each heat and cut up and etch, or otherwise prepare, the sections for examination for internal defects. Should injurious defects be found that evidence unsound steel or faulty foundry technique,

all of the castings made from that particular pattern, heat, and heat treatment charge may be rejected. All other rejected castings, including those cut up, shall be replaced by the manufacturer without charge.

S3. Bend Test

S3.1 One bend test shall be made from a test coupon from each master heat in accordance with Test Methods and Definitions A370 or Test Methods A1058, as applicable, and shall be machined to a 1 by ½-in. [25 by 13-mm] section with corners rounded to a radius not over 1⁄16 in. [1.6 mm].

S3.2 The specimen shall withstand being bent longitudinally at room temperature through an angle of 90° about a pin, the diameter of which shall be the specimen thickness for carbon steels, and 1 in. [25 mm] for other steels. The specimen shall show no cracks on the outside of the bent portion of the specimen.

S3.3 Bend test specimens may be cut from heat-treated castings instead of from test bars when agreed upon between manufacturer and purchaser.

S3.4 If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted from the same heat.

S4. Magnetic Particle Inspection

S4.1 Castings shall be examined for surface and near-surface discontinuities by magnetic particle inspection. The examination shall be in accordance with Guide E709, and types and degrees of discontinuities considered shall be judged by Reference Photographs E125. Extent of examination, time of examination, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. Specifications that may be used as a basis for such agreement are Specification A903/A903M and MSS SP 53.

S4.2 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S5. Radiographic Inspection

S5.1 Castings shall be examined for internal defects by means of X-rays or gamma rays. The procedure shall be in accordance with Guide E94/E94M, and types and degrees of discontinuities considered shall be judged by Reference Radiographs E186, E192, E280, E446, or E2660. Extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A specification that may be used as a basis for such agreement is MSS SP 54.

S5.2 Radiographic examination of castings may be performed before or after any heat treatment.

S5.3 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S6. Liquid Penetrant Inspection

S6.1 Castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The examination shall be in accordance with Practice E165/E165M. Areas to be inspected, time of inspection, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. A specification which may be used as a basis for such agreement is Specification A903/A903M.

S6.2 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S7. Ultrasonic Inspection

S7.1 Castings shall be examined for internal defects by means of ultrasonic inspection. The inspection procedure shall be in accordance with Practice A609/A609M. Extent of examination methods of testing and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

S7.2 Ultrasonic examination of casting of carbon and low-alloy steels shall be performed after at least one heat treatment above the transformation temperature range but need not be repeated after subsequent heat treatment.

S7.3 Personnel performing the examination shall be qualified in accordance with an acceptable written practice.

S8. Charpy Impact Test

S8.1 Charpy impact test properties shall be determined on each master heat from a set of three Charpy V-notch specimens made from a test coupon in accordance with Test Methods and Definitions A370 or Test Methods A1058, as applicable, and tested at a test temperature agreed upon by the manufacturer and purchaser. The sampling requirements shall be agreed upon between the manufacturer and purchaser (see 4.5). The acceptance requirements shall be energy absorbed, lateral expansion, percent shear area, or any combination thereof, and shall be agreed upon by the manufacturer and purchaser. Test specimens shall be prepared with a V-type notch and tested in accordance with Test Methods and Definitions A370 or Test Methods A1058, as applicable.

S8.2 *Absorbed Energy*—Average energy value of three specimens shall not be less than specified, with not more than one value permitted to fall below the minimum specified and no value permitted below the minimum specified for a single specimen.

S8.3 *Lateral Expansion*—Lateral expansion value shall be agreed upon by the manufacturer and purchaser.

S8.4 *Percent Shear Area*—Percent shear area shall be agreed upon by the manufacturer and purchaser.

S9. Drop Weight Tests

S9.1 Drop weight test properties shall be determined from each heat by preparing and testing either Type P1, P2, or P3 specimens in accordance with Test Method E208. The crack starter weld shall be deposited on the surface of the specimen that 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 “no break” performance.

S10. Examination of Weld Preparation

S10.1 Magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the inspection method specified for the casting. The method of performing magnetic particle or liquid penetrant examination