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Standard Specification for Steel Investment Castings General Requirements, for Pressure-Containing Parts¹

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, A 216/A 216MA 216/A 216M	A216/A216M
Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service	A216/A216M
Steel Castings, Martensitic Stainless and Alloy, for A 217/A 217MA 217/A 217M	A217/A217M
Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High- Temperature Service	A217/A217M
Castings, Austenitic, Austenitic-Ferritic (Duplex), A 351/A 351MA 351/A 351M	A351/A351M
Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure-Containing Parts	A351/A351M
Steel Castings, Ferritic and Martensitic, for Pressure A 352/A 352MA 352/A 352M	A352/A352M
Steel Castings, Ferritic and Martensitic, for Pressure- Containing Parts, Suitable for Low-Temperature Service	A352/A352M
Steel Castings, Alloy, Specially Heat-Treated, for A 389/A 389MA 389/A 389M	A389/A389M
Steel Castings, Alloy, Specially Heat-Treated, for Pressure-Containing Parts, Suitable for High- Temperature Service	A389/A389M
Steel Castings Suitable for Pressure Service A 487/A 487MA 487/A 487M	A487/A487M
Steel Castings Suitable for Pressure Service	A487/A487M

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 inch-pound or SI units are to be regarded separately as the standard. Within the text, the SI units are shown in brackets. The values 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. Inch-pound units are applicable for material ordered to Specification A 985 and SI units for material ordered to Specification A 985M.

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 non-conformance 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 and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:²

¹ This practice 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.

- 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, ~~Austenitic-Ferritic (Duplex),~~ 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 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
- 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 Specification for Chemical Passivation Treatments for Stainless Steel Parts
- A991/A991M Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
- E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E94 Guide for Radiographic Examination
- E125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings
- E165 ~~Test Method for Liquid Penetrant Examination~~ Practice for Liquid Penetrant Examination for General Industry
- E186 Reference Radiographs for Heavy-Walled (2 to 412-in. (51(50.8 to 114-mm)) Steel Castings
- E192 Reference Radiographs for 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 (412 to 12-in. (114 to 305-mm)) Steel Castings
- E340 Test Method 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. (51 mm) 2 in. (50.8 mm) in Thickness
- E709 Guide for Magnetic Particle Examination Testing
- 2.2 *ANSI Standard:*³
- B16.5 Steel 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 Manufacturer's Standardization Society of the Valve and Fitting Industry:*⁵
- MSS SP 53 Quality Standard for Steel Castings for Valves, Flanges and Fittings, and Other Piping Components (Dry Magnetic Particle Inspection Method)
- MSS SP 54 Quality Standard for Steel Castings for Valves, Flanges and Fittings, and Other Piping Components (Radiographic Inspection Method)
- 2.5 *SAE Aerospace Recommended Practice:*⁶
- ARP 1341 Determining Decarburization and Carburization in Finished Parts of Carbon and Low-Alloy Steel

3. Terminology

3.1 *Definitions*—The definitions in Test Methods and Definitions A 370A 370 and Terminology A 941A 941—The definitions in Test Methods and Definitions A370 and Terminology A941 are applicable to this specification and those listed in I.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 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, 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>.

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

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 *subheat, n*—a portion of master heat remelted with only minor additions for deoxidation for pouring into castings. Syn. melt, production heat.

4. Materials and Manufacture

4.1 *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 heats may be used

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 %	$0.03 \times \% C_L + 0.02$
	above 0.65 %	0.04 %
Manganese (Mn)	up to 1 %	$0.08 \times \% Mn_L + 0.01$
	above 1 %	0.09
Silicon (Si)	up to 0.60 %	$0.22 \times \% Si_L - 0.01$
	above 0.60 %	0.15 %
Phosphorus (P)	all	$0.13 \times \% P_L + 0.005$
Sulfur (S)	all	$0.36 \times \% S_L + 0.001$
Nickel (Ni)	up to 2 %	$0.10 \times \% Ni_L + 0.003$
	above 2 %	0.25 %
Chromium (Cr)	up to 2 %	$0.07 \times \% Cr_L + 0.04$
	above 2 %	0.18 %
Molybdenum (Mo)	up to 0.6 %	$0.04 \times \% Mo_L + 0.03$
Vanadium (V)	up to 0.25 %	$0.23 \times \% V_L + 0.004$
	above 0.25 %	0.06 %
Tungsten (W)	up to 0.10 %	$0.08 \times \% W_L + 0.02$
	above 0.10 %	0.02 %
Copper (Cu)	up to 0.15 %	$0.18 \times \% Cu_L + 0.02$
	above 0.15 %	0.05 %
Aluminum (Al)	up to 0.10 %	$0.08 \times \% Al_L + 0.02$
	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 the footnote C.

^C To compute the tolerances, consider the manganese limits 0.50 - 80 % of Grade WC4 of Specification ~~A-217/A-217M~~ A217/A217M. According to Table 1, the maximum permissible deviation of a product analysis below the lower limit 0.50 is $0.05 \% = (0.08 \times 0.50 + 0.01)$. 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 $0.074 \% = (0.08 \times 0.08 + 0.01)$. The highest acceptable product analysis of Grade WC4, therefore is 0.874. For Grade WCC of Specification ~~A-216/A-216M~~ 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 $1.49 = (1.40 + 0.09)$.

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 subheat.

4.2 *Re-Melting Process*—Subheats 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.

4.3 Heat Treatment:

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

4.3.2 Castings shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method ~~A-991/A-991M~~ A991/A991M.

4.3.2.1 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.

4.3.2.2 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.

4.4 Sampling:

4.4.1 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.

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

4.4.3 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.

4.4.4 Separately cast specimens for tension testing shall be cast in molds of the same type and material as those used for the castings, as shown in Figs. 1-4 and Table 2, except when Supplementary Requirement S26 is specified. The test coupon in Fig. 4 shall be employed only for austenitic alloy castings with cross sections less than 2½ in.⁷

5. Chemical Composition

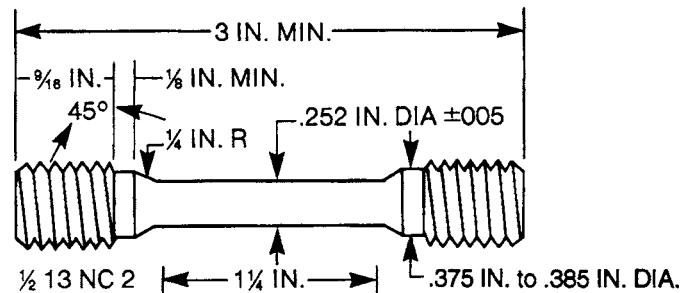
5.1 Chemical Analysis—Chemical analysis of materials covered by this specification shall be in accordance with Test Methods, Practices, and Terminology A-751A751.

5.2 Heat Analysis—An analysis of samples obtained in accordance with 4.4 or Supplementary Requirement S27 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 ¼ in. [1.6 mm] beneath the surface. The chemical composition thus determined shall be reported to the purchaser, or his 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, subheat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis shall be taken no closer than ¼ 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 E-353E353 or E-354E354, 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.

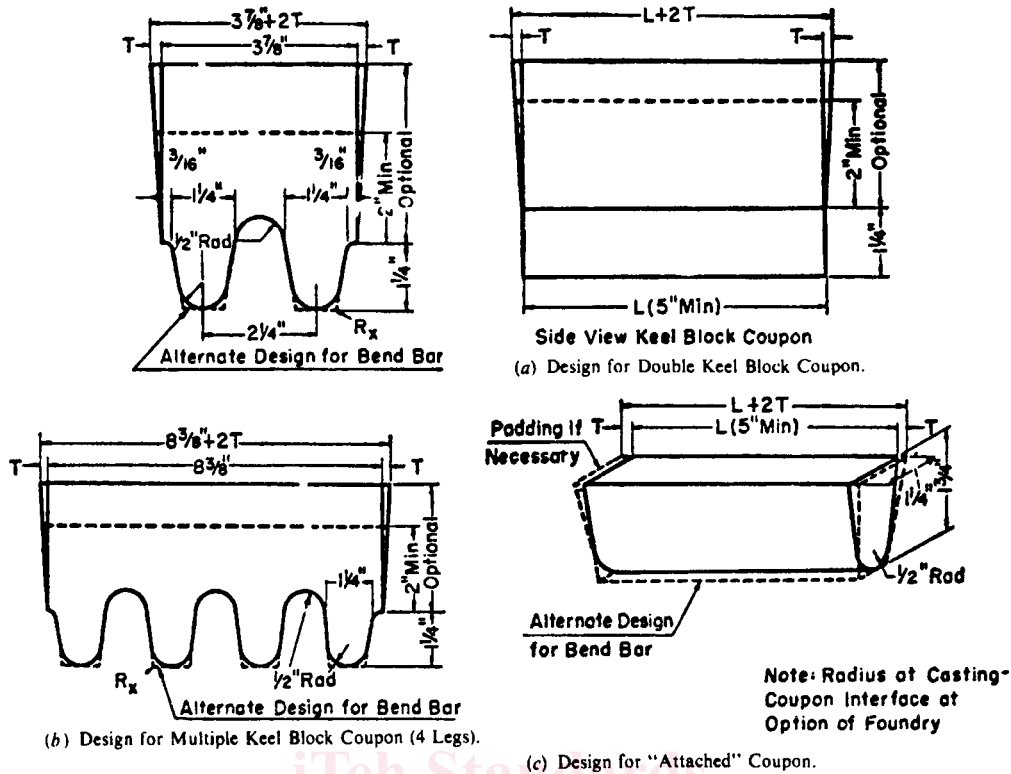
⁷ Information on the relationship of mechanical properties determined on test coupons obtained as specified in 4.4.4 with those obtained from the casting may be found in "The Steel Castings Handbook," Fifth Edition, Steel Founders' Society of America, 1980, pp. 15-35 through 15-43.



Metric Equivalents

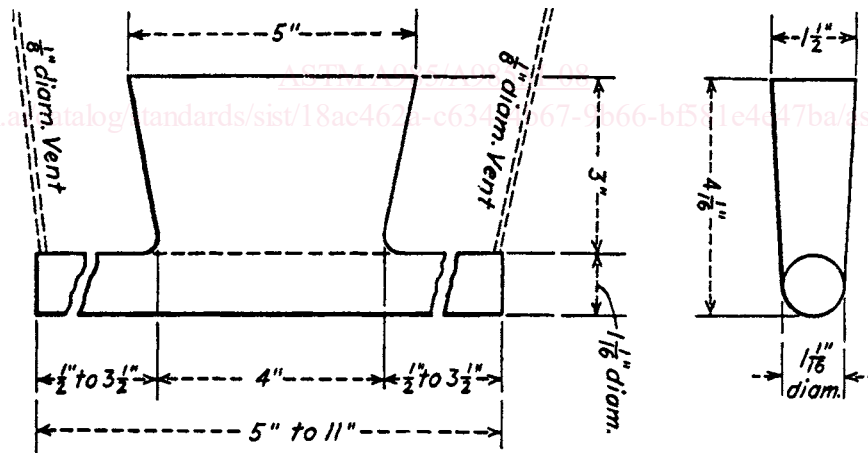
in.	0.005	1/16	0.252	0.375	0.385	9/16	1/4	3
[mm]	[0.15]	[3]	[6.40]	[9.50]	[9.75]	[15]	[30]	[75]

FIG. 1 Design and Dimensions of the ICI Test Bar



		Metric Equivalents							
In.	3/16	1/2	1 1/4	1 3/4	2	2 1/2	3 7/8	5	8 1/8
mm	4.8	13	32	45	51	57	98	127	213

FIG. 2 Test Coupons for Castings (see Table 2 for Details of Design)



NOTE—Pour through head; cover molten head with powered charcoal, coke dust, and so forth, immediately after pouring, in order to keep head fluid as long as possible.

Metric Equivalents			
in.	mm	in.	mm
1/8	3.2	3 1/2	88.9
1/2	12.7	4	101.6
1 1/16	27.0	4 1/16	103.2
1 1/2	38.1	5	127.0
3	76.2	11	279.4

FIG. 3 Test Block for Tension Test Specimen

NOTE 1—All commercial metals contain small amounts of various elements in addition to those which are specified. It is neither practical nor necessary

