



Designation: A957/A957M – 21

# Standard Specification for Investment Castings, Steel and Alloy, Common Requirements, for General Industrial Use<sup>1</sup>

This standard is issued under the fixed designation A957/A957M; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This specification covers a group of requirements that are mandatory for castings produced by the investment casting process to meet the metallurgical requirements of the following steel casting specifications issued by ASTM.

ASTM Designation	Title of Specification
A27/A27M	Steel Castings, Carbon, for General Application
A128/A128M	Steel Castings, Austenitic Manganese
A148/A148M	Steel Castings, High-Strength, for Structural Purposes
A297/A297M	Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat-Resistant, for General Application
A447/A447M	Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service
A494/A494M	Castings, Nickel and Nickel Alloy
A560/A560M	Castings, Chromium-Nickel Alloy
A732/A732M	Castings, Investment, Carbon and Low-Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures
A743/A743M	Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion-Resistant, for General Application
A744/A744M	Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
A747/A747M	Steel Castings, Stainless, Precipitation Hardening
A890/A890M	Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application
A915/A915M	Steel Castings, Carbon and Alloy, Chemical Requirements Similar to Standard Wrought Grades
A958/A958M	Steel Castings, Carbon and Alloy, with Tensile Requirements, Chemical Requirements Similar to Standard Wrought Grades
A1002	Castings, Nickel-Aluminum Ordered Alloy

1.2 This specification also covers a group of supplementary requirements that may be applied to the above specifications as indicated therein. These are provided for use when additional

<sup>1</sup> 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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testing or inspection is desired, and apply only when specified individually by the purchaser in the order.

1.3 When investment castings are ordered, the requirements stated in this specification form an integral part of the material specification. In cases of conflict, 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 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:*<sup>2</sup>
- A27/A27M Specification for Steel Castings, Carbon, for General Application
  - A128/A128M Specification for Steel Castings, Austenitic Manganese
  - A148/A148M Specification for Steel Castings, High Strength, for Structural Purposes
  - A297/A297M Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application
  - 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
  - A447/A447M Specification for Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto: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

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

**A494/A494M** Specification for Castings, Nickel and Nickel Alloy

**A560/A560M** Specification for Castings, Chromium-Nickel Alloy

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

**A732/A732M** Specification for Castings, Investment, Carbon and Low-Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures

**A743/A743M** Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application

**A744/A744M** Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service

**A747/A747M** Specification for Steel Castings, Stainless, Precipitation Hardening

**A751** Test Methods and Practices for Chemical Analysis of Steel Products

**A800/A800M** Practice for Estimating Ferrite Content of Stainless Steel Castings Containing Both Ferrite and Austenite

**A890/A890M** Specification for Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application

**A903/A903M** Specification for Steel Castings, Surface Acceptance Standards, Magnetic Particle and Liquid Penetrant Inspection

**A915/A915M** Specification for Steel Castings, Carbon, and Alloy, Chemical Requirements Similar to Standard Wrought Grades

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

**A958/A958M** Specification for Steel Castings, Carbon and Alloy, with Tensile Requirements, Chemical Requirements Similar to Standard Wrought Grades

**A967/A967M** 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

**A997** Practice for Investment Castings, Surface Acceptance Standards, Visual Examination

**A1002** Specification for Castings, Nickel-Aluminum Ordered Alloy

**A1058** Test Methods for Mechanical Testing of Steel Products—Metric

**A1067/A1067M** Specification for Test Coupons for Steel Castings

**A1080/A1080M** 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 Testing 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

**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 *SAE Standards:*<sup>3</sup>

**AMS 2750** Pyrometry

**ARP 1341** Determining Decarburization and Carburization in Finished Parts of Carbon and Low-Alloy Steel

### 3. Terminology

#### 3.1 Definitions:

3.1.1 The definitions in Test Methods and Definitions **A370**, Test Methods, Practices, and Terminology **A751**, 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 *investment casting, n*—a metal casting that is produced in a mold obtained by investing (surrounding) an expendable pattern with a ceramic slurry that 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.

3.2.2 *master heat, n*—a quantity of metal processed in a single furnace or refining vessel at one time in such a manner as to produce the desired composition and properties.

3.2.3 *sub-heat, n*—a portion of a master heat remelted without additional processing 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

<sup>3</sup> Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, <http://www.sae.org>.

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 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 specified in the individual specification or agreed upon between the customer and producer. Revert (gates, sprues, risers, and rejected castings) shall not be re-melted except in master heats.

#### **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 shall also be poured directly from each of the master heats.

**4.4.2** If castings are poured from a sub-heat, then the samples for chemical and other required testing shall also 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.

**4.4.3** Unless otherwise specified by the purchaser, test specimens may be taken from castings or from coupons cast integrally with the castings, in the same molds as the castings, or in separate molds.

#### **4.5 Heat Treatment:**

**4.5.1** Castings shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method **A991/A991M** or **AMS 2750**.

**4.5.2** When using furnaces surveyed in accordance with Test Method **A991/A991M**, the following requirements apply for heat treatments above 2000 °F [1100 °C]. 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.

**4.5.3** When using furnaces surveyed in accordance with **AMS 2750**, there are no additional requirements beyond those stated in **AMS 2750**.

**4.5.4** 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.

## **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 **4.4** or Supplementary Requirement **S20**, as appropriate, shall be made by the manufacturer to determine the percentages of the elements specified in the individual specification for the grade being poured. When drillings are used, they shall be taken not less than 1/16 in. [2 mm] beneath the surface. The chemical composition thus determined 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 of carbon and alloy steel shall be taken no closer than 1/16 in. [2 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, stainless steel, and nickel and cobalt based castings may vary from the specified limits by the amounts shown in **Table 1**, **Table 2**, and **Table 3**, respectively. The product analysis tolerances of **Tables 1-3** 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, and stainless 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 **S13** may be specified.

**NOTE 1**—All commercial metals contain small amounts of various elements in addition to those that 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.

**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 Requirements**

**6.1** The individual product specifications vary as to whether mechanical tests are required; for this reason, and to determine specific test requirements, the individual product specification should be reviewed. If mechanical testing is required by the product specification, sampling shall be in accordance with **4.4** or with Supplementary Requirement **S21**, as appropriate.

**6.2** Unless otherwise specified by the purchaser, when mechanical properties are required by the product specification, test coupons may be taken from castings, may be cast integrally with the castings, or may be cast in separate



**TABLE 1 Product Analysis Tolerances – Carbon and Low-Alloy Steels**

Element	Range, % <sup>A</sup>	Tolerances <sup>B,C</sup> Over Maximum or Under Minimum Limit, %
C	up to 0.65 above 0.65	$0.03 \times \% C_L + 0.02$ 0.04
Mn	up to 1 above 1	$0.08 \times \% Mn_L + 0.01$ 0.09
Si	up to 0.60 above 0.60	$0.22 \times \% Si_L - 0.01$ 0.15
P	all	$0.13 \times \% P_L + 0.005$
S	all	$0.36 \times \% S_L + 0.001$
Ni	up to 2 above 2	$0.10 \times \% Ni_L + 0.03$ 0.25
Cr	up to 2 above 2	$0.07 \times \% Cr_L + 0.04$ 0.18
Mo	up to 0.6 above 0.6	$0.04 \times \% Mo_L + 0.03$ 0.06
V	up to 0.25 above 0.25	$0.23 \times \% V_L + 0.004$ 0.06
W	up to 0.10 above 0.10	$0.08 \times \% W_L + 0.02$ 0.02
Cu	up to 0.15 above 0.15	$0.18 \times \% Cu_L + 0.02$ 0.05
Al	up to 0.10 above 0.10	$0.08 \times \% Al_L + 0.02$ 0.03

<sup>A</sup> The range denotes the composition limits up to which tolerances are computed by the equation, and above which the tolerances are given by a constant.

<sup>B</sup> 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.

<sup>C</sup> To illustrate the computation of the tolerance, consider the manganese maximum of 0.70 for an 0.30 carbon grade 65-35 in Specification A27/A27M. The maximum permissible deviation is  $(0.08 \times 0.70 + 0.01) = 0.066$ . Therefore, the highest acceptable product analysis is 0.766. Similarly, for an 0.20 carbon grade 70-40 in Specification A27/A27M, the maximum manganese content is 1.40; thus, the highest acceptable product analysis is  $(1.40 + 0.09) = 1.49$ .

molds made of the same material used for the production molds, cast in the same foundry and melted using the same foundry practices as those used for the castings, in accordance with Specification A1067/A1067M, Fig. 1, Fig. 2, Fig. 3, or Fig. 4, except when Supplementary Requirement S15 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].<sup>4</sup>

NOTE 2—Test Coupons for Large and Heavy Steel Castings—The test coupons in Specification A1067/A1067M, Fig. 1, are to be used for large and heavy steel castings. However, at the option of the foundry, the cross-sectional area and length of the standard coupon may be increased as desired.

NOTE 3—Bend Bar—If a bend bar is required, an alternate design (as shown by dotted lines in Specification A1067/A1067M, Fig. 1) is indicated.

NOTE 4—Specification A1067/A1067M, Fig 2—Pour through head; cover molten head with powdered charcoal, coke dust, and so forth, immediately after pouring, in order to keep head fluid as long as possible.

NOTE 5—Specification A1067/A1067M, Fig 4—Coupons produced in this manner are suitable for austenitic alloys only. The mold may be preheated for pouring to produce a sound coupon.

<sup>4</sup> Information on the relationship of mechanical properties determined on test coupons obtained as specified in 6.2 with those obtained from the casting may be found in *The Steel Casting Handbook*, Fifth Edition, Steel Founders' Society of America, 1980, pp. 15–35 through 15–43.

6.3 Choice of testing track from the options listed in Test Methods A1058 when material is ordered to an M-suffix (SI units) product standard should be identified by the purchaser in the ordering information. If the choice of test track is not specified in the order, then the default ASTM track shall be used as noted in Test Methods A1058.

6.4 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.

6.5 The specimens may be cast to shape or machined from coupons to dimensions in accordance with Test Methods and Definitions A370 or the ICI-type bar shown in Specification A1067/A1067M, Fig. 3.

6.6 To determine conformance 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.

6.6.1 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.

## 7. Workmanship, Finish, and Appearance

7.1 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.

## 8. Quality

8.1 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. Practice A997 or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

8.2 When additional inspection is desired, Supplementary Requirement S1, S2, S3, S4, or S5 may be specified.

## 9. Repair

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

## 10. Inspection

10.1 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.

**TABLE 2 Product Analysis Tolerances – Stainless Steels**

Element	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit	Element	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit	
Carbon	to 0.010, incl	0.002	Titanium	to 1.00, incl	0.05	
	over 0.010 to 0.030, incl	0.005		over 1.00 to 3.00, incl	0.07	
	over 0.030 to 0.20, incl	0.01	Cobalt	over 0.05 to 0.50, incl	0.01 <sup>A</sup>	
	over 0.20 to 0.60, incl	0.02		over 0.50 to 2.00, incl	0.02	
	over 0.60 to 1.20, incl	0.03		over 2.00 to 5.00, incl	0.05	
Manganese	to 1.00, incl	0.03	Columbium plus tantalum (niobium plus tantalum)	to 1.50, incl	0.05	
	over 1.00 to 3.00, incl	0.04		Tantalum	to 0.10, incl	0.02
	over 3.00 to 6.00, incl	0.05	Copper		to 0.50, incl	0.03
	over 6.00 to 10.00, incl	0.06			over 0.50 to 1.00, incl	0.05
	over 10.00 to 15.00, incl	0.10	over 1.00 to 3.00, incl	0.10		
over 15.00 to 20.00, incl	0.15	over 3.00 to 5.00, incl	0.15			
Phosphorus	to 0.040, incl	0.005	Aluminum	to 0.15, incl	-0.005, +0.01	
	over 0.040 to 0.20, incl	0.010		over 0.15 to 0.50, incl	0.05	
Sulfur	to 0.040, incl	0.005	over 0.50 to 2.00, incl	0.10		
	over 0.040 to 0.20, incl	0.010	Nitrogen	to 0.02, incl	0.005	
	over 0.20 to 0.50, incl	0.020		over 0.02 to 0.19, incl	0.01	
Silicon	to 1.00, incl	0.05	over 0.19 to 0.25, incl	0.02		
	over 1.00 to 3.00, incl	0.10	over 0.25 to 0.35, incl	0.03		
	over 3.00 to 6.00, incl	0.15	over 0.35 to 0.45, incl	0.04		
			over 0.45 to 0.55, incl	0.05		
Chromium	over 4.00 to 10.00, incl	0.10	Tungsten	to 1.00, incl	0.03	
	over 10.00 to 15.00, incl	0.15		over 1.00 to 2.00, incl	0.05	
	over 15.00 to 20.00, incl	0.20	Vanadium	to 0.50, incl	0.03	
	over 20.00 to 30.00, incl	0.25		over 0.50 to 1.50, incl	0.05	
Nickel	to 1.00, incl	0.03	Selenium	all	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					
Molybdenum	over 0.20 to 0.60, incl	0.03				
	over 0.60 to 2.00, incl	0.05				
	over 2.00 to 8.00, incl	0.10				

<sup>A</sup> Product analysis limits for cobalt under 0.05 % have not been established, and the manufacturer should be consulted for those limits.

[ASTM A957/A957M-21](https://standards.iteh.ai/catalog/standards/sist/e6e109a7-2ac3-4303-86be-6441509e8990/astm-a957-a957m-21)
<https://standards.iteh.ai/catalog/standards/sist/e6e109a7-2ac3-4303-86be-6441509e8990/astm-a957-a957m-21>

## 11. Rejection

11.1 Subsequent to acceptance at the manufacturer's works, material that is found to be unacceptable as determined by requirements specified in the order may be rejected by the purchaser. The manufacturer should be notified of such rejection. If the manufacturer is dissatisfied with the results of any tests performed by the purchaser, they may make claim for a rehearing.

## 12. Retests

12.1 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 master heat.

12.2 If the results of the mechanical tests for any heat, lot, or casting do not conform to the requirements specified, 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 6—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.

## 13. Keywords

13.1 casting; investment casting; master heat; steel; sub-heat



TABLE 3 Product Analysis Tolerances – Nickel and Cobalt Base Alloys

Element	Limit or Maximum of Specified Element, %	Variation Under Min or Over Max	Element	Limit or Maximum of Specified Element, %	Variation Under Min or Over Max	
Carbon	up to 0.02, incl	0.005	Aluminum	up to 0.10, incl	0.02	
	over 0.02 to 0.20, incl	0.01		over 0.10 to 0.50, incl	0.05	
	over 0.20 to 0.60, incl	0.02		over 0.50 to 2.00, incl	0.10	
	over 0.60 to 1.00, incl	0.03		over 2.00 to 5.00, incl	0.20	
Manganese	up to 1.00, incl	0.03	Boron	over 5.00 to 10.00, incl	0.25	
	over 1.00 to 3.00, incl	0.04		over 10.00 to 15.00, incl	0.30	
	over 3.00 to 6.00, incl	0.07		up to 0.01, incl	0.002	
	over 6.00 to 10.00, incl	0.10		over 0.01 to 0.05, incl	0.005	
Silicon	up to 0.05, incl	0.02	Iron	over 0.05 to 0.15, incl	0.010	
	over 0.05 to 0.25, incl	0.03		up to 0.20, inc	0.02	
	over 0.25 to 0.50, incl	0.04		over 0.20 to 0.75, incl	0.03	
	over 0.50 to 1.00, incl	0.05		over 0.75 to 2.50, incl	0.05	
Phosphorus	over 1.00 to 4.50, incl	0.10	Copper	over 2.50 to 5.00, incl	0.07	
	all	0.005		over 5.00 to 10.00, incl	0.10	
	Sulfur	up to 0.02, incl		0.003	over 10.00 to 15.00, incl	0.15
		over 0.02 to 0.06, incl		0.005	over 15.00 to 30.00, incl	0.30
Chromium		up to 5.00, incl	0.10	over 30.00 to 50.00, incl	0.45	
		over 5.00 to 15.00, incl	0.15	Vanadium	up to 0.20, incl	0.02
	over 15.00 to 25.00, incl	0.25	over 0.20 to 0.50, incl		0.03	
	over 25.00 to 35.00, incl	0.30	over 0.50 to 5.00, incl		0.04	
over 35.00 to 45.00, incl	0.40	over 5.00 to 10.00, incl	0.05			
Nickel	over 45.00 to 50.00, incl	0.50	Yttrium	over 10.00 to 20.00, incl	0.10	
	up to 1.00, incl	0.05		over 20.00 to 30.00, incl	0.15	
	over 1.00 to 5.00, incl	0.10		over 30.00 to 40.00, inc	0.20	
	over 5.00 to 10.00, incl	0.15		over 40.00 to 60.00, incl	0.35	
Cobalt	over 10.00 to 20.00, incl	0.20	Zirconium	over 60.00 to 80.00, inc	0.45	
	over 20.00 to 30.00, incl	0.30		over 80.00 to 99.00, incl	0.60	
	over 30.00 to 40.00, incl	0.35		Lanthanum	up to 0.50, incl	0.04
	over 40.00 to 60.00, incl	0.45			over 0.50 to 1.50, incl	0.05
over 60.00 to 80.00, inc	0.45	Cerium	up to 0.050, incl		0.005	
over 80.00 to 99.00, incl	0.60		over 0.050 to 0.10, incl		0.010	
up to 0.10, incl	0.01		over 0.10 to 0.20, incl	0.015		
over 0.10 to 0.20, incl	0.02		Hafnium	up to 0.10, incl	0.01	
over 0.20 to 1.00, incl	0.03	over 0.10 to 0.20, incl		0.02		
over 1.00 to 5.00, incl	0.05	Rhenium		up to 0.20, incl	0.01	
over 5.00 to 10.00, incl	0.10			up to 0.050, incl	0.005	
over 10.00 to 15.00, incl	0.15		over 0.050 to 0.10, incl	0.010		
over 15.00 to 20.00, incl	0.20		over 0.10 to 0.20, incl	0.015		
Molybdenum	over 20.00 to 25.00, incl	0.25	Platinum	up to 1.50, incl	0.05	
	over 25.00 to 30.00, incl	0.30		over 1.50 to 3.00, incl	0.10	
	over 30.00 to 35.00, incl	0.35		Oxygen	up to 1.50, incl	0.05
	over 35.00 to 50.00, incl	0.50			over 1.50 to 3.00, incl	0.10
up to 1.00, incl	0.03	over 3.00 to 5.00, incl	0.15			
over 1.00 to 3.00, incl	0.05	over 5.00 to 7.00, incl	0.20			
Tungsten	over 3.00 to 5.00, incl	0.10	Nitrogen	up to 0.50, incl	0.03	
	over 5.00 to 10.00, incl	0.20		up to 0.010, incl	0.005	
	over 10.00 to 20.00, incl	0.25		up to 0.02, incl	0.005	
	Niobium <sup>4</sup> and/or Tantalum	up to 1.50, incl		0.05	over 0.02 to 0.19, incl	0.01
over 1.50 to 3.00, incl		0.10	over 0.19 to 0.25, incl	0.02		
3.00 to 5.00, incl		0.15	over 0.25 to 0.35, incl	0.03		
over 5.00 to 7.00, incl		0.20	over 0.35 to 0.45, incl	0.04		
Titanium	over 7.00 to 10.00, incl	0.25	over 0.45 to 0.60, incl	0.05		
	over 10.00 to 13.00, incl	0.30	Magnesium	up to 0.10, incl	0.01	
	up to 0.10, incl	0.02		Lead	up to 0.01, incl	0.002
	over 0.10 to 0.50, inc	0.03			Tin	up to 0.01, incl
over 0.50 to 1.00, incl	0.04	over 0.01 to 0.05, incl				0.005
over 1.00 to 2.00, incl	0.05	Zinc	up to 0.01, incl			0.002
			over 0.01 to 0.05, incl	0.005		

**TABLE 3** *Continued*

Element	Limit or Maximum of Specified Element, %	Variation Under Min or Over Max	Element	Limit or Maximum of Specified Element, %	Variation Under Min or Over Max
Titanium	over 2.00 to 3.50, incl	0.07			
	over 3.50 to 5.00, incl	0.10			
	over 5.00 to 10.00, incl	0.20			

<sup>4</sup> Niobium (Nb) and columbium (Cb) both designate element 41.

## 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. Magnetic Particle Examination

S1.1 Castings shall be examined for surface and near-surface discontinuities by magnetic particle examination. The examination shall be in accordance with Guide **E709**. The extent of examination and the basis for acceptance shall be agreed upon between the manufacturer and the purchaser. Specification **A903/A903M** may be used as a basis for such agreement.

### S2. Radiographic Examination

S2.1 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 examination shall be agreed upon between the manufacturer and purchaser.

### S3. Liquid Penetrant Examination

S3.1 Castings shall be examined for surface discontinuities by means of liquid penetrant examination. The examination shall be in accordance with Practice **E165/E165M**. Areas to be inspected, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser. Specification **A903/A903M** may be used as a basis for such agreement.

### S4. Ultrasonic Examination

S4.1 Castings shall be examined for internal defects by means of ultrasonic examination. The examination 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.

### S5. Examination of Weld Preparation

S5.1 Magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the examination method specified for the casting. The method of performing magnetic particle or liquid penetrant examination shall be in accordance with either Guide **E709** or Practice

**E165/E165M**. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs **E125**, of Degree 2 in sections up to 2 in. [50 mm] thick and of Degree 3 in sections over 2 in. [50 mm] thick, shall be acceptable.

### S6. Certification

S6.1 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 date) and was found to meet the requirements.

S6.2 A manufacturer's certification 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, provided it conforms to any existing EDI agreement between the purchaser and the supplier.

### S7. Prior Approval of Major Weld Repairs

S7.1 Major weld repairs, as defined and agreed upon between the manufacturer and purchaser, shall be subject to the prior approval of the purchaser.

### S8. Marking

S8.1 The castings shall be marked for identification or traceability, or both. The content of the marking and the method of marking, including size, location, and style, shall be as agreed upon between the purchaser and the producer.

### S9. Charpy Impact Test

S9.1 Charpy impact test properties shall be determined from a set of three Charpy V-notch specimens made from a test coupon in accordance with Specification **A1067/A1067M**, and tested at a test temperature agreed upon between the manufacturer and the purchaser. The sampling requirements shall be agreed upon between the manufacturer and purchaser (see 4.4). The acceptance requirements shall be energy absorbed, lateral expansion, or percent shear area, or any combination thereof, and shall be that agreed upon between the manufacturer and purchaser. Test specimens shall be prepared and tested in