



Designation: A781/A781M – 21

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

This standard is issued under the fixed designation A781/A781M; 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 requirements of the following steel casting specifications issued by ASTM. If the product specification specifies different requirements, the product specification shall prevail.

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
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 testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 The requirements of the individual material specification and this general specification shall prevail in the sequence named.

<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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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
- 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

<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

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

**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

**A802/A802M** Practice for Steel Castings, Surface Acceptance Standards, Visual Examination

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

**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

**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

**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

2.2 *SAE Standard*:<sup>3</sup>

**AMS 2750** Pyrometry

### 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**.

3.1.2 *test coupon, n*—the part from which the test specimen will be extracted.

3.1.3 *test specimen, n*—the part that will be acted upon in a test.

### 4. Materials and Manufacture

4.1 *Melting Process*—The steel shall be made by open-hearth or electric furnace process with or without separate refining, such as argon-oxygen-decarburization (AOD), unless otherwise specified in the individual specification.

#### 4.2 Heat Treatment:

4.2.1 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**.

4.2.2 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.

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

4.2.4 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**.

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

**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 <sub>L</sub> 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 a 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 a 0.20 carbon grade 70-40 in Specification **A27/A27M**, the maximum manganese content is 1.40; thus, the highest acceptable product analysis is  $(1.40 + 0.09) = 1.49$ .

**5.2 Heat Analysis**—An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified in the individual specification for the grade being poured. The analysis shall be made from a test sample, preferably taken during the pouring of the heat. When drillings are used, they shall be taken not less than ¼ in. [6.4 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 heat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis shall be taken no closer than ¼ in. [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, 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  $R_2$ , 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.

**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

**NOTE 1**—The tension testing requirements of this specification are intended only to characterize the tensile properties of the heat for determination of conformance to the requirements of the applicable product specification. Such testing procedures are not intended to define the upper or lower limits of tensile properties at all possible test locations within a heat. It is well known and documented that tensile properties will vary within a heat or individual casting as a function of chemical composition, processing, testing procedure, and other factors.<sup>4</sup> It is, therefore, incumbent on designers and engineers to use sound engineering judgement when using tension test results.

**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.

**6.2** Unless otherwise specified by the purchaser, when mechanical properties are required by the product specification, test coupons may be cast integrally with the castings, or as separate blocks, in accordance with Specification **A1067/A1067M**, Fig. 1, Fig. 2, or Fig. 4, except when Supplementary Requirement S15 is specified. The test coupon in Specification **A1067/A1067M**, Fig. 4 may be employed only for austenitic stainless steel and nickel-base alloy castings with cross sections less than 2½ in. [65 mm].

**6.3** Test specimens may be cut from heat-treated castings, at the producer's or the purchaser's option, instead of from separately cast test coupons.

**6.4** 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**.

**6.5** 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.

**6.6** The specimens may be cast to shape or machined from coupons to dimensions in accordance with Test Methods and Definitions **A370**.

**6.7** To determine conformance with the tension test requirements, an observed value or calculated value shall be

<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, pp.15–35 through 15–43, 1980.

**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	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	over 5.00 to 10.00, incl	0.20			
	over 0.040 to 0.20, incl	0.010	Aluminum	to 0.15, incl	-0.005, +0.01		
Sulfur	to 0.040, incl	0.005		over 0.15 to 0.50, incl	0.05		
	over 0.040 to 0.20, incl	0.010		over 0.50 to 2.00, incl	0.10		
	over 0.20 to 0.50, incl	0.020	Nitrogen	to 0.02, incl	0.005		
Silicon	to 1.00, incl	0.05		over 0.02 to 0.19, incl	0.01		
	over 1.00 to 3.00, incl	0.10		over 0.19 to 0.25, incl	0.02		
	over 3.00 to 6.00, incl	0.15		over 0.25 to 0.35, incl	0.03		
Chromium	over 4.00 to 10.00, incl	0.10		over 0.35 to 0.45, incl	0.04		
	over 10.00 to 15.00, incl	0.15	over 0.45 to 0.55, incl	0.05			
	over 15.00 to 20.00, incl	0.20	Tungsten	to 1.00, incl	0.03		
	over 20.00 to 30.00, incl	0.25		over 1.00 to 2.00, incl	0.05		
Nickel	to 1.00, incl	0.03	Vanadium	to 0.50, incl	0.03		
	over 1.00 to 5.00, incl	0.07		over 0.50 to 1.50, incl	0.05		
	over 5.00 to 10.00, incl	0.10	Selenium	all	0.03		
	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.

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.

## 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, the dimensions of the casting shall be as predicated by the pattern.

## 8. Quality

8.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A802/A802M 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.

8.3 Rejectable indications shall not be peened, plugged, or impregnated.

## 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.



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, incl	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, incl	0.20	
	over 5.00 to 10.00, incl	0.15		over 40.00 to 60.00, incl	0.30	
Cobalt	over 10.00 to 20.00, incl	0.20	Zirconium	over 60.00 to 80.00, incl	0.45	
	over 20.00 to 30.00, incl	0.25		over 80.00 to 99.00, incl	0.60	
	over 30.00 to 40.00, incl	0.30		Lanthanum	up to 0.10, incl	0.01
	over 40.00 to 60.00, incl	0.35			over 0.10 to 0.20, incl	0.02
over 60.00 to 80.00, incl	0.45	Cerium	up to 0.20, incl		0.01	
over 80.00 to 99.00, incl	0.60		up to 0.050, incl		0.005	
up to 0.10, incl	0.01		over 0.050 to 0.10, incl	0.010		
over 0.10 to 0.20, incl	0.02		over 0.10 to 0.20, incl	0.015		
Molybdenum	over 0.20 to 1.00, incl	0.03	Hafnium	up to 1.50, incl	0.05	
	over 1.00 to 3.00, incl	0.05		over 1.50 to 3.00, incl	0.10	
	over 3.00 to 5.00, incl	0.10		Rhenium	up to 1.50, incl	0.05
	over 5.00 to 20.00, incl	0.15			over 1.50 to 3.00, incl	0.10
over 20.00 to 30.00, incl	0.25	Platinum	up to 0.50, incl		0.03	
over 30.00 to 50.00, incl	0.50		up to 0.010, incl		0.005	
Tungsten	up to 1.00, incl		0.04	Nitrogen	up to 0.02, incl	0.005
	over 1.00 to 3.00, incl		0.10		over 0.02 to 0.19, incl	0.01
	over 3.00 to 5.00, incl	0.15	over 0.19 to 0.25, incl		0.02	
	over 5.00 to 10.00, incl	0.20	over 0.25 to 0.35, incl		0.03	
Niobium <sup>4</sup> and/or Tantalum	over 10.00 to 20.00, incl	0.25	Magnesium	over 0.35 to 0.45, incl	0.04	
	up to 1.50, incl	0.05		over 0.45 to 0.60, incl	0.05	
	over 1.50 to 3.00, incl	0.10		up to 0.10, incl	0.01	
	3.00 to 5.00, incl	0.15		Lead	up to 0.01, incl	0.002
over 5.00 to 7.00, incl	0.20	Tin	up to 0.01, incl		0.002	
over 7.00 to 10.00, incl	0.25		over 0.01 to 0.05, incl		0.005	
over 10.00 to 13.00, incl	0.30		Zinc		up to 0.01, incl	0.002
Titanium	up to 0.10, incl			0.02	over 0.01 to 0.05, incl	0.005
	over 0.10 to 0.50, incl	0.03		Oxygen	up to 0.010, incl	0.005
	over 0.50 to 1.00, incl	0.04			Nitrogen	up to 0.02, incl
	over 1.00 to 2.00, incl	0.05	over 0.02 to 0.19, incl			0.01

**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.

All tests and inspections, with the exception of product analysis (5.3), shall be made at the place of manufacture unless otherwise agreed.

## 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. Retesting

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 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 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.

## 13. Keywords

13.1 castings; common requirements; steel and alloy

## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

### S1. 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. Extent of examination and the basis for acceptance shall be agreed upon between the manufacturer and purchaser.

### 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 E446, E186, or E280. Extent of examination and basis for acceptance 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.

### 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. 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. [50.8 mm] thick, and of Degree 3 in sections over 2 in. 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 manufacturer's name or identification mark and the pattern number shall be cast or stamped on all castings. When further specified, the heat numbers or serial numbers shall be marked on individual castings.

### **S9. Charpy Impact Test**

S9.1 Charpy impact test properties shall be determined by testing a set of three Charpy V-notch specimens made from each heat at a test temperature agreed upon by the manufacturer and purchaser. The material from which the test specimens are prepared shall be cast in accordance with 6.2. The acceptance requirements shall be either energy absorbed, lateral expansion, or percent shear area, or all three, and shall be that agreed upon between the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A370, or the test track specified by the purchaser when referencing Test Methods A1058.

S9.2 *Absorbed Energy*—Average energy value of three specimens shall be not 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.

S9.3 *Lateral Expansion*—Lateral expansion value shall be agreed upon between the manufacturer and purchaser.

S9.4 *Percent Shear Area*—Percent shear area shall be agreed upon between the manufacturer and purchaser.

### **S10. Hardness Test**

S10.1 Hardness measurements at specified locations on the castings shall be made in accordance with Test Methods and Definitions A370, or the test track specified by the purchaser when referencing Test Methods A1058, and reported.

### **S11. Specified Ferrite Content Range**

S11.1 The chemical composition of the heat shall be controlled such that the ferrite content, as determined by the chemical composition procedure of Practice A800/A800M, shall be in conformance with the specified ferrite content range.

S11.2 The specified ferrite content range shall be as agreed upon between the manufacturer and the purchaser. The minimum specified ferrite content range shall be 10 %, with the minimum ferrite content being no lower than the percent

necessary to achieve the minimum mechanical properties required for the alloy.

S11.3 Should the purchaser wish to have the ferrite content determined by either magnetic response or metallographic methods, the purchaser should impose Supplementary Requirement S1 or S2 of Practice A800/A800M.

### **S12. Test Report**

S12.1 The manufacturer shall supply a test report to the purchaser giving the results of all tests performed, including chemical analysis.

### **S13. Unspecified Elements**

S13.1 Chemical analysis and limits for elements not specified for the grade ordered shall be as agreed upon between the manufacturer and purchaser.

### **S14. Tension Test from Castings**

S14.1 In addition to the tension test required by the material specification, test material shall be cut from the casting. The mechanical properties and location for the test material shall be agreed upon by the manufacturer and purchaser.

### **S15. Alternate Mechanical Test Coupons and Specimen Locations for Castings**

S15.1 Test coupons may be cast integrally with the castings or separately. Separately cast coupons shall be heat treated together with the castings they represent.

S15.2 In the following, the casting thickness,  $T$ , is the maximum thickness of the casting exclusive of padding added for directional solidification, flanges, appendages, and sections designated by the designer as noncritical. The order, inquiry, and drawing shall designate what the test dimension,  $T$ , is for the casting.

S15.3 One of the following shall apply:

S15.3.1 The longitudinal centerline of the test specimen shall be taken at least  $\frac{1}{4} T$  from the  $T$  dimension surface and all of the gage length must be at least  $1 T$  from any other heat-treated surface, exclusive of the surface opposite the  $T$  dimension surface. (See Specification A1067/A1067M, Fig. 5 (a).) For cylindrical castings, the longitudinal centerline of the specimens shall be taken at least  $\frac{1}{4} T$  from the outside or inside and all of the gage length must be at least  $T$  from the as-heat-treated end. (See Specification A1067/A1067M Fig. 5 (b).) For ferritic and martensitic castings, partial severing of test coupons prior to final heat treatment is permitted.

S15.3.2 Where separately cast test coupons are used, the dimension shall not be less than  $3 T$  by  $3 T$  by  $T$ , and each specimen shall meet the requirements of S15.3.1, except that when  $T$  exceeds 5 in. [125 mm], the dimension may be 15 by 15 by 5 in. [375 by 375 by 125 mm], by agreement between the manufacturer and the purchaser. The test coupon shall be of the same heat of steel and shall receive substantially the same casting practices as the production casting it represents. Centrifugal castings may be represented by statically cast coupons. (See Specification A1067/A1067M, Fig. 6.)

S15.3.3 When agreed upon by the manufacturer and the purchaser, castings that are cast or machined to essentially the finished configuration prior to heat treatment shall have test