



# Standard Test Methods for Chemical Analysis of Cast Iron—All Types<sup>1</sup>

This standard is issued under the fixed designation E351; 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.

*This standard has been approved for use by agencies of the U.S. Department of Defense.*

## 1. Scope

1.1 These test methods cover the chemical analysis of pig iron, gray cast iron (including alloy and austenitic), white cast iron, malleable cast iron, and ductile (nodular) iron having chemical compositions within the following limits:

Element	Composition Range, %
Aluminum	0.003 to 0.50
Antimony	0.005 to 0.03
Arsenic	0.02 to 0.10
Bismuth	0.001 to 0.03
Boron	0.001 to 0.10
Cadmium	0.001 to 0.005
Carbon	1.25 to 4.50
Cerium	0.005 to 0.05
Chromium	0.01 to 30.00
Cobalt	0.01 to 4.50
Copper	0.03 to 7.50
Lead	0.001 to 0.15
Magnesium	0.002 to 0.10
Manganese	0.06 to 2.50
Molybdenum	0.01 to 5.00
Nickel	0.01 to 36.00
Phosphorus	0.01 to 0.90
Selenium	0.001 to 0.06
Silicon	0.10 to 6.0
Sulfur	0.005 to 0.25
Tellurium	0.001 to 0.35
Tin	0.001 to 0.35
Titanium	0.001 to 0.20
Tungsten	0.001 to 0.20
Vanadium	0.005 to 0.50
Zinc	0.005 to 0.20

1.2 The test methods in this standard are contained in the sections indicated below:

	Sections
Carbon, Graphitic, by the Direct Combustion Infrared Absorption Method (1 % to 3 %)	108
Carbon, Total, by the Combustion Gravimetric Method (1.25 % to 4.50 %)— <i>Discontinued</i>	97
Cerium and Lanthanum by the Direct Current Plasma Atomic Emission Spectrometry Method (Ce: 0.003 % to 0.5 %; La: 0.001 % to 0.30 %)	237

<sup>1</sup> These test methods are under the jurisdiction of ASTM Committee E01 on Analytical Chemistry for Metals, Ores, and Related Materials and are the direct responsibility of Subcommittee E01.01 on Iron, Steel, and Ferroalloys.

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Chromium by the Atomic Absorption Method (0.006 % to 1.00 %)	208
Chromium by the Peroxydisulfate Oxidation—Titration Method (0.006 % to 1.00 %)	218
Chromium by the Peroxydisulfate-Oxidation Titrimetric Method (0.05 % to 30.0 %)— <i>Discontinued</i>	
Cobalt by the Ion-Exchange—Potentiometric Titration Method (2.0 % to 4.5 %)	53
Cobalt by the Nitroso-R-Salt Spectrophotometric Method (0.01 % to 4.50 %)	61
Copper by the Neocuproine Spectrophotometric Method (0.03 % to 7.5 %)	116
Copper by the Sulfide Precipitation-Electrodeposition Gravimetric Method (0.03 % to 7.5 %)	81
Lead by the Ion-Exchange—Atomic Absorption Method (0.001 % to 0.15 %)	126
Magnesium by the Atomic Absorption Method (0.002 % to 0.10 %)	71
Manganese by the Periodate Spectrophotometric Method (0.10 % to 2.00 %)	8
Manganese by the Peroxydisulfate-Arsenite Titrimetric Method (0.10 % to 3.5 %)	152
Molybdenum by the Ion Exchange–8-Hydroxyquinoline Gravimetric Method	257
Molybdenum by the Spectrophotometric Method (0.01 % to 1.5 %)	196
Nickel by the Dimethylglyoxime Gravimetric Method (0.1 % to 36.00 %)	168
Nickel by the Ion Exchange-Atomic Absorption Method (0.005 % to 1.00 %)	176
Phosphorus by the Alkalimetric Method (0.02 % to 0.90 %)	160
Phosphorus by the Molybdenum Blue Spectrophotometric Method (0.02 % to 0.90 %)	18
Silicon by the Gravimetric Method (0.1 % to 6.0 %)	46
Sulfur by the Gravimetric Method— <i>Discontinued</i>	30
Sulfur by the Combustion-Iodate Titration Method (0.005 % to 0.25 %)— <i>Discontinued</i>	37
Sulfur by the Chromatographic Gravimetric Method— <i>Discontinued</i>	
Tin by the Solvent Extraction-Atomic Absorption Method (0.002 % to 0.10 %)	186
Tin by the Sulfide-Iodometric Titration Method (0.01 % to 0.35 %)	89
Titanium, Total, by the Diantiprylmethane Spectrophotometric Method (0.006 % to 0.35 %)	246
Vanadium by the Atomic Absorption Method (0.006 % to 0.15 %)	227

1.3 Procedures for the determination of carbon and sulfur not included in these test methods can be found in Test Methods E1019.

1.4 Some of the composition ranges given in 1.1 are too broad to be covered by a single method and therefore this standard contains multiple methods for some elements. The user must select the proper method by matching the information given in the Scope and Interference sections of each method with the composition of the alloy to be analyzed.

1.5 The values stated in SI units are to be regarded as standard.

1.6 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. Specific hazards statements are given in Section 6 and in special “Warning” paragraphs throughout these Methods.

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- [D1193 Specification for Reagent Water](#)
- [E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications](#)
- [E50 Practices for Apparatus, Reagents, and Safety Considerations for Chemical Analysis of Metals, Ores, and Related Materials](#)
- [E60 Practice for Analysis of Metals, Ores, and Related Materials by Spectrophotometry](#)
- [E135 Terminology Relating to Analytical Chemistry for Metals, Ores, and Related Materials](#)
- [E173 Practice for Conducting Interlaboratory Studies of Methods for Chemical Analysis of Metals \(Withdrawn 1998\)<sup>3</sup>](#)
- [E350 Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron](#)
- [E352 Test Methods for Chemical Analysis of Tool Steels and Other Similar Medium- and High-Alloy Steels](#)
- [E353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys](#)
- [E380 Practice for Use of the International System of Units \(SI\) \(the Modernized Metric System\) \(Withdrawn 1997\)<sup>3</sup>](#)
- [E882 Guide for Accountability and Quality Control in the Chemical Analysis Laboratory](#)
- [E1019 Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Fusion Techniques](#)
- [E1024 Guide for Chemical Analysis of Metals and Metal Bearing Ores by Flame Atomic Absorption Spectrophotometry \(Withdrawn 2004\)<sup>3</sup>](#)
- [E1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition](#)

### 2.2 Other Document:<sup>4</sup>

- [ISO 5725 Precision of Test Methods—Determination of Repeatability and Reproducibility for Inter-Laboratory Tests](#)

## 3. Terminology

3.1 For definitions of terms used in these test methods, refer to Terminology [E135](#).

<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.

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

<sup>4</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

## 4. Significance and Use

4.1 These test methods for the chemical analysis of metals and alloys are primarily intended as referee methods to test such materials for compliance with compositional specifications, particularly those under the jurisdiction of ASTM Committee A04 on Iron Castings. It is assumed that all who use these test methods will be trained analysts capable of performing common laboratory procedures skillfully and safely. It is expected that work will be performed in a properly equipped laboratory under appropriate quality control practices such as those described in Guide [E882](#).

## 5. Apparatus, Reagents, and Instrumental Practices

5.1 *Apparatus*—Specialized apparatus requirements are listed in the Apparatus section in each method.

### 5.2 Reagents:

5.2.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society where such specifications are available.<sup>5</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water as conforming to Type I or Type II of Specification [D1193](#). Type III or IV may be used if they effect no measurable change in the blank or sample.

5.3 *Spectrophotometric Practice*—Spectrophotometric practice prescribed in these test methods shall conform to Practice [E60](#).

## 6. Hazards

6.1 For precautions to be observed in the use of certain reagents and equipment in these methods, refer to Practices [E50](#).

## 7. Sampling

7.1 For procedures for sampling the material, reference shall be made to Practice [E1806](#).

## 8. Interlaboratory Studies and Rounding Calculated Values

8.1 These test methods have been evaluated in accordance with Practice [E173](#) (withdrawn 1997) or ISO 5725. The Reproducibility R2 of [E173](#) corresponds to the Reproducibility Index R of E1601. The Repeatability R1 of [E173](#) corresponds to the Repeatability Index r of E1601.

8.2 Calculated values shall be rounded to the desired number of places in accordance with the Rounding Method of Practice [E29](#).

<sup>5</sup> *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

## MANGANESE BY THE METAPERIODATE SPECTROPHOTOMETRIC METHOD

### 9. Scope

9.1 This test method covers the determination of manganese in compositions from 0.10 % to 2.00 %.

### 10. Summary of Method

10.1 Manganous ions are oxidized to permanganate ions by reaction with metaperiodate ions. Solutions of the samples are fumed with  $\text{HClO}_4$  so that the effect of metaperiodate ion is limited to the oxidation of manganese. Spectrophotometric measurement is made at approximately 545 nm.

### 11. Concentration Range

11.1 The recommended concentration range is 0.15 mg to 0.8 mg of manganese per 50 mL of solution, using a 1-cm cell (Note 1) and a spectrophotometer with a band width of 10 nm or less.

NOTE 1—This method has been written for cells having a 1-cm light path and a narrow-band instrument. The concentration range depends upon band width and spectral region used as well as cell optical path length. Cells having other dimensions may be used, provided suitable adjustments can be made in the amounts of sample and reagents used.

### 12. Stability of Color

12.1 The color is stable for at least 24 h.

### 13. Interferences

13.1 The elements ordinarily present do not interfere.  $\text{HClO}_4$  treatment, which is used in the procedure, yields solutions which can be highly colored due to the presence of Cr (VI) ions. Although these ions and other colored ions in the sample solution undergo no further change in color quality upon treatment with metaperiodate ion, the following precautions must be observed when filter spectrophotometers are used: Select a filter with maximum transmittance between 545 nm and 565 nm. The filter must transmit not more than 5 % of its maximum at a wavelength shorter than 530 nm. The band width of the filter should be less than 30 nm when measured at 50 % of its maximum transmittance. Similar restrictions apply with respect to the wavelength region employed when other wide-band instruments are used.

13.2 The spectral transmittance curve of permanganate ions exhibits two useful minima, one at approximately 526 nm, and the other at 545 nm. The latter is recommended when a narrow-band spectrophotometer is used.

### 14. Reagents

14.1 *Manganese, Standard Solution* (1 mL = 0.032 mg Mn)—Transfer the equivalent of 0.4000 g of assayed, high-purity manganese (purity: 99.99 % minimum), to a 500-mL volumetric flask and dissolve in 20 mL of  $\text{HNO}_3$  by heating. Cool, dilute to volume, and mix. Using a pipet, transfer 20 mL to a 500-mL volumetric flask, dilute to volume, and mix.

14.2 *Nitric-Phosphoric Acid Mixture*—Cautiously, while stirring, add 100 mL of  $\text{HNO}_3$  and 400 mL of  $\text{H}_3\text{PO}_4$  to 400 mL of water. Cool, dilute to 1 L, and mix. Prepare fresh as needed.

14.3 *Potassium Metaperiodate Solution* (7.5 g/L)—Dissolve 7.5 g of potassium metaperiodate ( $\text{KIO}_4$ ) in 200 mL of hot  $\text{HNO}_3$  (1 + 1), add 400 mL of  $\text{H}_3\text{PO}_4$ , cool, dilute to 1 L, and mix.

14.4 *Water, Pretreated with Metaperiodate*—Add 20 mL of  $\text{KIO}_4$  solution to 1 L of water, mix, heat at not less than 90 °C for 20 min to 30 min, and cool. Use this water to dilute solutions to volume that have been treated with  $\text{KIO}_4$  solution to oxidize manganese, and thus avoid reduction of permanganate ions by any reducing agents in the untreated water. **Warning**—Avoid the use of this water for other purposes.

### 15. Preparation of Calibration Curve

15.1 *Calibration Solutions*—Using pipets, transfer 5 mL, 10 mL, 15 mL, 20 mL, and 25 mL of manganese standard solution (1 mL = 0.032 mg Mn) to 50-mL borosilicate glass volumetric flasks, and, if necessary, dilute to approximately 25 mL. Proceed as directed in 15.3.

15.2 *Reference Solution*—Transfer approximately 25 mL of water to a 50-mL borosilicate glass volumetric flask. Proceed as directed in 15.3.

15.3 *Color Development*—Add 10 mL of  $\text{KIO}_4$  solution, and heat the solutions at not less than 90 °C for 20 min to 30 min (Note 2). Cool, dilute to volume with pretreated water, and mix.

NOTE 2—Immersing the flasks in a boiling water bath is a preferred means of heating them for the specified period to ensure complete color development.

#### 15.4 Spectrophotometry:

15.4.1 *Multiple-Cell Spectrophotometer*—Measure the cell correction using the Reference Solution (15.2) in absorption cells with a 1-cm light path and using a light band centered at approximately 545 nm. Using the test cell, take the spectrophotometric readings of the calibration solutions versus the Reference Solution (15.2).

15.4.2 *Single-Cell Spectrophotometer*—Transfer a suitable portion of the Reference Solution (15.2) to an absorption cell with a 1-cm light path and adjust the spectrophotometer to the initial setting, using a light band centered at approximately 545 nm. While maintaining this adjustment, take the spectrophotometric readings of the calibration solutions.

15.5 *Calibration Curve*—Follow the instrument manufacturer's instructions for generating the calibration curve.

### 16. Procedure

#### 16.1 Test Solution:

16.1.1 Select and weigh a sample in accordance with the following:

Manganese, %	Sample Weight, g	Tolerance in Sample Weight, mg	Dilution, mL
0.01 to 0.5	0.80	0.5	100
0.45 to 1.0	0.35	0.3	100
0.85 to 2.0	0.80	0.5	500

Transfer it to a 300-mL Erlenmeyer flask.

16.1.2 To dissolve samples that do not require HF, add 8 mL to 10 mL of  $\text{HCl}$  (1 + 1), and heat. Add  $\text{HNO}_3$  as needed to