



Standard Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron¹

This standard is issued under the fixed designation E350; 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 carbon steels, low-alloy steels, silicon electrical steels, ingot iron, and wrought iron having chemical compositions within the following limits:

Element	Composition Range, %
Aluminum	0.001 to 1.50
Antimony	0.002 to 0.03
Arsenic	0.0005 to 0.10
Bismuth	0.005 to 0.50
Boron	0.0005 to 0.02
Calcium	0.0005 to 0.01
Cerium	0.005 to 0.50
Chromium	0.005 to 3.99
Cobalt	0.01 to 0.30
Columbium (Niobium)	0.002 to 0.20
Copper	0.005 to 1.50
Lanthanum	0.001 to 0.30
Lead	0.001 to 0.50
Manganese	0.01 to 2.50
Molybdenum	0.002 to 1.50
Nickel	0.005 to 5.00
Nitrogen	0.0005 to 0.04
Oxygen	0.0001 to 0.03
Phosphorus	0.001 to 0.25
Selenium	0.001 to 0.50
Silicon	0.001 to 5.00
Sulfur	0.001 to 0.60
Tin	0.002 to 0.10
Titanium	0.002 to 0.60
Tungsten	0.005 to 0.10
Vanadium	0.005 to 0.50
Zirconium	0.005 to 0.15

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

	Sections
Aluminum, Total, by the 8-Quinolinol Gravimetric Method (0.20 % to 1.5 %)	124 – 131
Aluminum, Total, by the 8-Quinolinol Spectrophotometric Method (0.003 % to 0.20 %)	76 – 86
Aluminum, Total or Acid-Soluble, by the Atomic Absorption Spectrometry Method (0.005 % to 0.20 %)	308 – 317

¹ 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.

Current edition approved Aug. 15, 2012. Published September 2012. Originally approved in 1968. Last previous edition approved in 2005 as E350 – 95 (2005)^{ε1}. DOI: 10.1520/E0350-12.

	Sections
Antimony by the Brilliant Green Spectrophotometric Method (0.0002 % to 0.030 %)	142 – 151
Bismuth by the Atomic Absorption Spectrometry Method (0.02 % to 0.25 %)	298 – 307
Boron by the Distillation-Curcumin Spectrophotometric Method (0.0003 % to 0.006 %)	208 – 219
Calcium by the Direct-Current Argon Plasma Atomic Emission Spectroscopy Method (0.0005 % to 0.010 %)	289 – 297
Carbon, Total, by the Combustion Gravimetric Method (0.05 % to 1.80 %)— <i>Discontinued 1995</i>	
Cerium and Lanthanum by the Direct Current Plasma Atomic Emission Spectrometry Method (0.003 % to 0.50 % Cerium, 0.001 % to 0.30 % Lanthanum)	249 – 257
Chromium by the Atomic Absorption Spectrometry Method (0.006 % to 1.00 %)	220 – 229
Chromium by the Peroxydisulfate Oxidation-Titration Method (0.05 % to 3.99 %)	230 – 238
Cobalt by the Nitroso-R Salt Spectrophotometric Method (0.01 % to 0.30 %)	53 – 62
Copper by the Atomic Absorption Spectrometry Method (0.004 % to 0.5 %)	279 – 288
Copper by the Neocuproine Spectrophotometric Method (0.005 % to 1.50 %)	114 – 123
Lead by the Ion-Exchange—Atomic Absorption Spectrometry Method (0.001 % to 0.50 %)	132 – 141
Manganese by the Atomic Absorption Spectrometry Method (0.005 % to 2.0 %)	269 – 278
Manganese by the Metaperiodate Spectrophotometric Method (0.01 % to 2.5 %)	9 – 18
Manganese by the Peroxydisulfate-Arsenite Titrimetric Method (0.10 % to 2.50 %)	164 – 171
Molybdenum by the Thiocyanate Spectrophotometric Method (0.01 % to 1.50 %)	152 – 163
Nickel by the Atomic Absorption Spectrometry Method (0.003 % to 0.5 %)	318 – 327
Nickel by the Dimethylglyoxime Gravimetric Method (0.1 % to 5.00 %)	180 – 187
Nickel by the Ion-Exchange-Atomic-Absorption Spectrometry Method (0.005 % to 1.00 %)	188 – 197
Phosphorus by the Alkalimetric Method (0.02 % to 0.25 %)	172 – 179
Phosphorus by the Molybdenum Blue Spectrophotometric Method (0.003 % to 0.09 %)	19 – 30
Silicon by the Molybdenum Blue Spectrophotometric Method (0.01 % to 0.06 %)	103 – 113
Silicon by the Gravimetric Titration Method (0.05 % to 3.5 %)	46 – 52
Sulfur by the Combustion-Iodate Titration Method (0.005 % to 0.3 %)	37 – 45
Tin by the Sulfide-Iodometric Titration Method (0.01 % to 0.1 %)	95 – 102
Tin by the Solvent Extraction-Atomic Absorption Spectrometry Method (0.002 % to 0.10 %)	198 – 207

Sections

Titanium, Total, by the Diantipyrylmethane Spectrophotometric Method (0.025 % to 0.30 %)	258 – 268
Vanadium by the Atomic Absorption Spectrometry Method (0.006 % to 0.15 %)	239 – 248

1.3 Test methods for the determination of several elements not included in this standard 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 test method and therefore this standard contains multiple test methods for some elements. The user must select the proper test method by matching the information given in the Scope and Interference sections of each test method with the composition of the alloy to be analyzed.

1.5 The values stated in SI units are to be regarded as standard. In some cases, exceptions allowed in **IEEE/ASTM SI 10** are also used.

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 test methods.

2. Referenced Documents

2.1 ASTM Standards:²

- 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)³
- E319** Practice for the Evaluation of Single-Pan Mechanical Balances
- E351** Test Methods for Chemical Analysis of Cast Iron—All Types
- 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
- E354** Test Methods for Chemical Analysis of High-

Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys

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)³

E1097 Guide for Determination of Various Elements by Direct Current Plasma Atomic Emission Spectrometry

E1806 Practice for Sampling Steel and Iron for Determination of Chemical Composition

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

2.2 *ISO Standard*:⁴

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**.

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 Committees A01 on Steel, Stainless Steel, and Related Alloys and 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 test method.

5.2 *Reagents*:

5.2.1 *Purity of Reagents*—Unless otherwise indicated, all reagents used in these test methods shall conform to the reagent grade specifications of the American Chemical Society.⁵ Other chemicals may be used, provided it is first ascertained that they are of sufficiently high purity to permit their use without adversely affecting the expected performance of the determination, as indicated in the Precision and Bias section.

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.

³ The last approved version of this historical standard is referenced on www.astm.org.

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

⁵ *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC, www.chemistry.org. 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, <http://www.usp.org>.

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.

6. Hazards

6.1 For precautions to be observed in the use of certain reagents and equipment in these test 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 using Practice E173 or ISO 5725.

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

MANGANESE BY THE METAPERIODATE SPECTROPHOTOMETRIC METHOD

9. Scope

9.1 This test method covers the determination of manganese in compositions from 0.01 % to 2.5 %.

10. Summary of Test Method

10.1 Manganous ions are oxidized to permanganate ions by reaction with metaperiodate ions. Solutions of the samples are fumed with perchloric acid 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 from 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 test 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. Perchloric acid 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 HNO₃ 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 HNO₃ and 400 mL of H₃PO₄ 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 (KIO₄) in 200 mL of hot HNO₃ (1 + 1), add 400 mL of H₃PO₄, cool, dilute to 1 L, and mix.

14.4 *Water, Pretreated with Metaperiodate*—Add 20 mL of KIO₄ 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 KIO₄ solution to oxidize manganese, and thus avoid reduction of permanganate ions by any reducing agents in the untreated water. **Caution**—Avoid the use of this water for other purposes.

15. Preparation of Calibration Curve

15.1 *Calibration Solutions*—Using pipets, transfer (5, 10, 15, 20, 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 KIO₄ 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