



Standard Test Method for Analysis of Low-Alloy Steels by Wavelength Dispersive X-Ray Fluorescence Spectrometry¹

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1. Scope

1.1 This test method covers the wavelength dispersive X-ray fluorescence analysis of low-alloy steels for the following elements:

Element	Mass Fraction Range, %
Calcium	0.001 to 0.007
Chromium	0.04 to 2.5
Cobalt	0.03 to 0.2
Copper	0.03 to 0.6
Manganese	0.04 to 2.5
Molybdenum	0.005 to 1.5
Nickel	0.04 to 3.0
Niobium	0.002 to 0.1
Phosphorus	0.010 to 0.08
Silicon	0.06 to 1.5
Sulfur	0.009 to 0.1
Vanadium	0.012 to 0.6

NOTE 1—Unless exceptions are noted, mass fraction ranges can be extended and additional elements can be included by the use of suitable reference materials and measurement conditions. Deviations from the published scope must be validated by experimental means. See Guide E2857 for information on validation options.

1.2 The values stated in the International System of Units (SI) are to be regarded as standard. The values given in parentheses are mathematical conversions to other units that are provided for information only, because they may be used in older software and laboratory procedures.

1.3 *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 precautionary statements are given in Section 10.

¹ This test method is under the jurisdiction of ASTM Committee E01 on Analytical Chemistry for Metals, Ores, and Related Materials and is the direct responsibility of Subcommittee E01.01 on Iron, Steel, and Ferroalloys.

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2. Referenced Documents

2.1 ASTM Standards:²

- E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E135 Terminology Relating to Analytical Chemistry for Metals, Ores, and Related Materials
- E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
- E1361 Guide for Correction of Interelement Effects in X-Ray Spectrometric Analysis
- E1621 Guide for Elemental Analysis by Wavelength Dispersive X-Ray Fluorescence Spectrometry
- E2857 Guide for Validating Analytical Methods

3. Terminology

3.1 For definitions of terms used in this test method, refer to Terminology E135.

4. Summary of Test Method

4.1 The test specimen is finished to a clean uniform surface and then irradiated with a primary X-ray beam of high energy. The secondary X-rays produced are dispersed by means of crystals, and the intensities (also called count rates) are measured by suitable detectors at selected wavelengths. Radiation measurements are made based on the time required to reach a fixed number of counts, or on the total counts obtained for a fixed time. Mass fractions of the elements are determined by relating the measured intensities from unknown specimens to analytical curves prepared with suitable reference materials. Either a fixed-channel, polychromator system or a sequential, wavelength dispersive monochromator system may be used to provide simultaneous or sequential determinations of elements, respectively.

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.

5. Significance and Use

5.1 This test method is suitable for manufacturing control and for verifying that a product meets specifications. This test method provides rapid, multi-element determinations with sufficient accuracy to ensure product quality and to minimize production delays. The analytical performance data may be used as a benchmark to determine if similar X-ray spectrometers provide equivalent precision and accuracy, or if the performance of a particular X-ray spectrometer has changed.

5.2 Calcium is sometimes added to steel to affect inclusion shape to enhance certain mechanical properties of steel. This test method is useful for determining the residual calcium in the steel after such treatment.

5.2.1 Because calcium occurs primarily in inclusions, the precision of this test method is a function of the distribution of the calcium-bearing inclusions in the steel. The variation of determinations on freshly prepared surfaces will give some indication of the distribution of these inclusions.

6. Interferences

6.1 Inter-element or matrix effects may exist for some elements in 1.1. Mathematical corrections may be used to compensate for these effects. Various mathematical correction procedures are commonly utilized. See Guide E1361 and Guide E1621. Any of these procedures is acceptable that will achieve analytical accuracy equivalent to that provided by this test method.

6.2 Spectroscopic interferences or line overlaps may be observed, if the energy resolution of the measurement conditions is insufficient. Mathematical corrections may be used to calibrate the overlaps and perform corrections. See Guide E1621.

6.3 Because trace amounts of calcium are being determined with this test method, exercise care not to contaminate the specimen. Calcium in the grinding medium will contaminate the specimen to the extent that erratic and incorrect results will be obtained. Therefore, the grinding medium shall be analyzed for calcium, and only materials that are free of calcium shall be used.

7. Apparatus

7.1 Specimen Preparation Equipment:

7.1.1 *Surface Grinder or Sander with Abrasive Belts, Disks, or Lathe*, capable of providing a flat, uniform surface on the reference materials and test specimens.

7.1.1.1 When calcium is to be determined, 240-grit, calcium-free silicon carbide belts or disks shall be used.

7.2 *Wavelength Dispersive Spectrometer*, designed for X-ray fluorescence analysis, and equipped with specimen holders and a specimen chamber. The chamber may contain a specimen spinner, and must be equipped for vacuum or helium-flushed operation for the determination of elements of atomic number 20 (calcium) or lower.

7.2.1 *X-Ray Tubes*, with targets of various high-purity elements, that are capable of continuous operation at required potentials and currents, and will excite the elements to be determined.

7.2.1.1 For the determination of calcium, only chromium target tubes were tested. Other targets may be used provided they produce data that meets the precision and bias in Section

7.2.2 *Analyzing Crystals*, flat or curved crystals with optimized capability for the diffraction of the wavelengths of interest.

7.2.3 *Collimator*, for limiting the characteristic X-rays to a parallel bundle when flat crystals are used. Curved crystals do not require a collimator.

7.2.4 *Detectors*, sealed or gas-flow proportional-type, scintillation counters, or equivalent.

7.2.5 *Vacuum System*, providing for the determination of elements whose radiation is absorbed by air, atomic number 20 (calcium) or lower. The system shall consist of a vacuum pump, gage, and electrical controls to provide automatic pumpdown of the optical path and maintain a controlled pressure, usually 13 Pa (100 μ m Hg) or less, controlled to ± 3 Pa (± 20 μ m Hg).

8. Reagents and Materials

8.1 *Detector Gas (P-10)*, consisting of a mixture of 90 % argon and 10 % methane, for use with gas-flow proportional counters only.

9. Reference Materials

9.1 *Certified Reference Materials* are available from national metrology institutes, other government organizations, and commercial suppliers.

9.2 *Reference Materials* with matrices similar to that of the test specimen and containing varying amounts of the elements to be determined may be used provided they have been chemically analyzed in using valid, independent test methods. These reference materials shall be homogeneous, and free of voids or porosity.

9.3 The reference materials shall cover the mass fraction ranges of the elements being sought. A minimum of three reference materials shall be used for each element. When correction factors for matrix effects and spectroscopic interferences are to be calculated from the empirical data as calibration parameters, at least one additional reference material is needed for each correction parameter. Refer to Guide E1361 and Guide E1621.

NOTE 2—Calculation of correction factors for matrix effects and spectroscopic interferences from X-ray theory can be used to reduce the number of reference materials required for calibration.

10. Hazards

10.1 U.S. Nuclear Regulatory Commission Standards for ionizing radiation as found in the Code of Federal Regulations 10 CFR Part 19, "Notices, Instructions and Reports to Workers: Inspection and Investigations" and 10 CFR Part 20, "Standards for Protection Against Radiation"³ shall be observed at all X-ray emission spectrometer installations in the U.S. It is also

³ Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, <http://www.access.gpo.gov>