



Designation: E3193 – 23

Standard Test Method for Measurement of Lead (Pb) by Flame Atomic Absorption Spectrophotometry (FAAS)¹

This standard is issued under the fixed designation E3193; 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.

1. Scope

1.1 This test method covers the determination of lead (Pb) in airborne particulate, dust by wipe and micro-vacuuming, paint, and soil collected in and around buildings and related structures by flame atomic absorption spectrophotometry (FAAS) and is derived from Test Methods [D4185](#) and [E1613](#).

1.2 The sensitivity, detection limit, and optimum working concentration for lead (Pb) are given in [Table 1](#).

1.3 The values stated in SI units are to be regarded as standard. No other values of measurement are included in this standard.

1.3.1 *Exception*—The SI and inch-pound units shown for wipe and micro-vacuuming sampling data are to be individually regarded as standard for wipe and micro-vacuuming sampling data ([14.4.2](#) and [14.4.3](#)).

1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

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:*²

[D1193](#) Specification for Reagent Water

[D1356](#) Terminology Relating to Sampling and Analysis of Atmospheres

¹ This test method is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.12 on Sampling and Analysis of Lead for Exposure and Risk Assessment.

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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.

[D4185](#) Test Method for Measurement of Metals in Workplace Atmospheres by Flame Atomic Absorption Spectrophotometry

[D4210](#) Practice for Intralaboratory Quality Control Procedures and a Discussion on Reporting Low-Level Data (Withdrawn 2002)³

[D4532](#) Test Method for Respirable Dust in Workplace Atmospheres Using Cyclone Samplers

[D4697](#) Guide for Maintaining Test Methods in the User's Laboratory (Withdrawn 2009)³

[D4840](#) Guide for Sample Chain-of-Custody Procedures

[D6785](#) Test Method for Determination of Lead in Workplace Air Using Flame or Graphite Furnace Atomic Absorption Spectrometry

[D6966](#) Practice for Collection of Settled Dust Samples Using Wipe Sampling Methods for Subsequent Determination of Metals

[D7035](#) Test Method for Determination of Metals and Metalloids in Airborne Particulate Matter by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)

[D7144](#) Practice for Collection of Surface Dust by Microvacuum Sampling for Subsequent Determination of Metals and Metalloids

[E456](#) Terminology Relating to Quality and Statistics

[E631](#) Terminology of Building Constructions

[E691](#) Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

[E1188](#) Practice for Collection and Preservation of Information and Physical Items by a Technical Investigator

[E1583](#) Practice for Evaluating Laboratories Engaged in Determination of Lead in Paint, Dust, Airborne Particulates, and Soil Taken From and Around Buildings and Related Structures

[E1605](#) Terminology Relating to Lead in Buildings

[E1613](#) Test Method for Determination of Lead by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES), Flame Atomic Absorption Spectrometry (FAAS), or Graphite Furnace Atomic Absorption Spectrometry (GFAAS) Techniques (Withdrawn 2021)³

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

TABLE 1 FAAS Instrumental Detection Limit and Optimum Working Concentration for Lead (Pb)

Element	Detection Limit, µg/mL (approximately three times standard deviation of blank) ⁴	Optimum Linear Range Upper Limit, µg/mL	Elements, Compound Classes, and Oxides
Pb	0.02	10	Inorganic compounds, airborne particulate, paint, dust by wipe and micro-vacuuming, soil

⁴ Detection limit represents ideal laboratory conditions; variability due to sampling, digestion, reagents, and sample handling has not been taken into account.

- [E1644 Practice for Hot Plate Digestion of Dust Wipe Samples for the Determination of Lead](#)
- [E1645 Practice for Preparation of Dried Paint Samples by Hotplate or Microwave Digestion for Subsequent Lead Analysis](#)
- [E1726 Practice for Preparation of Soil Samples by Hotplate Digestion for Subsequent Lead Analysis](#)
- [E1727 Practice for Field Collection of Soil Samples for Subsequent Lead Determination](#)
- [E1728 Practice for Collection of Settled Dust Samples Using Wipe Sampling Methods for Subsequent Lead Determination](#)
- [E1729 Practice for Field Collection of Dried Paint Samples for Subsequent Lead Determination](#)
- [E1741 Practice for Preparation of Airborne Particulate Lead Samples Collected During Abatement and Construction Activities for Subsequent Analysis by Atomic Spectrometry \(Withdrawn 2009\)³](#)
- [E1792 Specification for Wipe Sampling Materials for Lead in Surface Dust](#)
- [E1864 Practice for Evaluating Quality Systems of Organizations Conducting Facility and Hazard Assessments for Lead in Paint, Dust, Airborne Particulate, and Soil in and around Buildings and Related Structures \(Withdrawn 2011\)³](#)
- [E1908 Practice for Sample Selection of Debris Waste from a Building Renovation or Lead Abatement Project for Toxicity Characteristic Leaching Procedure \(TCLP\) Testing for Leachable Lead \(Pb\)](#)
- [E1979 Practice for Ultrasonic Extraction of Paint, Dust, Soil, and Air Samples for Subsequent Determination of Lead](#)
- [E2115 Guide for Conducting Lead Hazard Assessments of Dwellings and of Other Child-Occupied Facilities](#)
- [E2239 Practice for Record Keeping and Record Preservation for Lead Hazard Activities](#)
- [E2271/E2271M Practice for Clearance Examinations Following Lead Hazard Reduction Activities in Multifamily Dwellings](#)
- [E2913/E2913M Practice for Hotplate Digestion of Lead from Composited Wipe Samples](#)
- [E2914/E2914M Practice for Ultrasonic Extraction of Lead from Composited Wipe Samples](#)
- [E3074/E3074M Practice for Clearance Examinations Following Lead Hazard Reduction Activities in Single Family Dwellings, in Individual Units of Multifamily Dwellings, and in Other Child-Occupied Facilities](#)

2.2 *Code of Federal Regulations*:⁴

[40 CFR 745 Lead-Based Paint Poisoning Prevention in Certain Residential Structures](#)

2.3 *Governmental Agency Guidance*:⁵

[U.S. Environmental Protection Agency National Lead Laboratory Accreditation Program \(NLLAP\)](#)

[U.S. Environmental Protection Agency SW-846 Test Method 1311: Toxicity Characteristic Leaching Procedure](#)

2.4 *ISO Standard*:⁶

[ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories](#)

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminologies [D1356](#), [E456](#), [E631](#), and [E1605](#).

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *analysis run, n*—a period of measurement time on a given analytical instrument during which data are calculated from a single calibration curve (or single set of curves).

3.2.1.1 *Discussion*—Recalibration of a given instrument produces a new analysis run.

3.2.2 *calibration standards, n*—solutions of known analyte concentrations used to calibrate instruments.

3.2.2.1 *Discussion*—Calibration standards must be matrix matched to the acid content present in sample digestates or extracts and must be measured prior to analyzing samples.

3.2.3 *initial calibration blank (ICB), n*—a standard containing no analyte that is used for the initial calibration and zeroing of the instrument response.

3.2.3.1 *Discussion*—The ICB must be matrix matched to the acid content of sample extracts and digestates. The ICB must be measured during and after calibration. The measured value is to be (at most) less than five times the IDL.

3.2.4 *initial calibration verification (ICV), n*—a solution (or set of solutions) of known analyte concentration used to verify calibration standard levels; the concentration of analyte is to be near the mid-range of the linear curve that is made from a stock

⁴ Available from U.S. Government Publishing Office, 732 N. Capitol St., NW, Washington, DC 20401, <http://www.gpo.gov>.

⁵ Available from United States Environmental Protection Agency (EPA), William Jefferson Clinton Bldg., 1200 Pennsylvania Ave., NW, Washington, DC 20460, <http://www.epa.gov>.

⁶ Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <http://www.iso.org>.

solution having a different manufacturer or manufacturer lot identification than the calibration standards.

3.2.4.1 *Discussion*—The ICV must be matrix matched to the acid content of sample extracts or digestates. The ICV must be measured after calibration and before measuring any sample digestates or extracts. The measured value is to fall within $\pm 10\%$ of the known value.

3.2.5 *instrumental detection limit (IDL), n*—the lowest concentration at which the instrumentation can distinguish analyte content from the background generated by a minimal matrix.

3.2.5.1 *Discussion*—The IDL is usually determined by the manufacturer. The IDL can be determined from blank, acidified, deionized, or ultrapure water as the matrix and from the same calculation methods used to determine a method detection limit (MDL). Typical lead (Pb) IDL for FAAS is 0.05 $\mu\text{g/mL}$.

3.2.6 *instrumental QC standards, n*—these provide information on measurement performance during the instrumental analysis portion of the overall analyte measurement process. They include CCBs, CCVs, ICBs, and ICVs.

3.2.7 *method blank, n*—a digestate or extract that reflects the maximum treatment given any one sample within a sample batch, except that no sample is placed into the digestion or extraction vessel. (The same reagents and processing conditions that are applied to field samples within a batch are also applied to the method blank.)

3.2.7.1 *Discussion*—Analysis results from method blanks provide information on the level of potential contamination experienced by samples processed within the batch.

3.2.8 *quantitation limit, n*—an instrumental measurement value that is used to provide a lower concentration limit for reporting quantitative analysis data for a given analytical method.

3.2.8.1 *Discussion*—Any sample that generates a lead measurement below the quantitation limit is reported as a less-than value using the quantitation limit value multiplied by the appropriate dilution factors resulting from preparation of the sample for instrumental analysis.

3.2.9 *quantitative analysis, n*—an analysis run on sample digestates or extracts (or serial dilutions thereof) that includes instrumental QC standards.

3.2.9.1 *Discussion*—Data from this analysis run are used to calculate and report final lead analysis results.

3.2.10 *reporting limit, n*—the lowest concentration of analyte in a sample that can be reported with a defined, reproducible level of certainty.

3.2.10.1 *Discussion*—This value is usually based on the low standard used for instrument calibration. For analyses in the United States of America subject to 40 CFR 745 and the National Lead Laboratory Accreditation Program (NLLAP), the reporting limit for a specific sample matrix must be at least twice the MDL for that same sample matrix.

3.2.11 *semiquantitative analysis, n*—an analysis run that is performed on highly diluted sample digestates or extracts for the purpose of determining the approximate analyte level in the digest.

3.2.11.1 *Discussion*—This analysis run is generally per-

formed without inserting instrumental QC standards except for calibration standards. Data from this run are used for determining serial dilution requirements for sample digestates or extracts to keep them within the linear range of the instrument.

3.2.12 *serial dilution, n*—a method of producing a less concentrated solution through one or more consecutive dilution steps.

3.2.12.1 *Discussion*—A dilution step for a standard or sample solution is performed by volumetrically placing a small aliquot (of known volume) of a higher concentrated solution into a volumetric flask and diluting to volume with water containing the same acid levels as those found in original sample digestates or extracts.

3.2.13 *spiked duplicate sample, n*—two portions of a homogenized sample that were targeted for addition of analyte and fortified with all the target analytes before preparation.

3.2.13.1 *Discussion*—Analysis results for these samples are used to provide information on the precision and bias of the overall analysis process.

3.2.14 *spiked sample, n*—a sample portion (split from an original sample) to which an additional known amount of analyte has been added.

3.2.14.1 *Discussion*—Analysis results for spiked samples are used to provide information on the precision and bias of the overall analysis process.

3.2.15 *un-spiked sample, n*—a portion of a homogenized sample that was targeted for the addition of analyte but is not fortified with target analytes before sample preparation.

3.2.15.1 *Discussion*—Analysis results for this sample are used to correct for native analyte levels in the spiked and spiked duplicate samples.

4. Summary of Test Method

4.1 A sample digestate or extract is analyzed for lead content using FAAS. Instrumental QC samples are analyzed along with sample digestates or extracts in order to ensure adequate instrumental performance.

NOTE 1—Digestion is an example of an extraction process. Other examples of extraction processes are ultrasonic extraction and leaching.

4.2 Samples and standards are aspirated into the flame of an absorption spectrophotometer. A lead (Pb) hollow cathode or electrodeless discharge lamp provides the characteristic radiation energy for lead. The absorption of this characteristic energy by lead atoms in the flame is related to the concentration of lead in the aspirated sample. The flame and operating conditions for lead are listed in [Table 2](#).⁷

5. Significance and Use

5.1 This test method is intended for use with other standards that address the collection and preparation of samples (airborne particulate, dusts by wipe and micro-vacuuming, dried paint chips, and soils) that are obtained during the assessment or mitigation of lead hazards from buildings and related structures.

⁷ The boldface numbers in parentheses refer to a list of references at the end of this standard.

TABLE 2 FAAS Flame and Operating Conditions for Lead (Pb)

Element	Type of Flame	Analytical Wavelength, nm	Interferences ^A	Remedy ^A	Reference
Pb	Air-C ₂ H ₂ (oxidizing)	217.0 283.3	Ca, high concentration SO ₄ ⁻²	<i>B</i>	(1)

^A High concentrations of silicon in the sample can cause an interference and may cause aspiration problems. If large amounts of silica are extracted from the samples, the samples should be allowed to stand for several hours and centrifuged or filtered to remove the silica.

^B Samples are periodically analyzed by the method of additions to check for chemical interferences. If interferences are encountered, determinations must be made by the standard additions method or, if the interferent is identified, it may be added to the standards.

5.2 Laboratories analyzing samples obtained during the assessment or mitigation of lead hazards from buildings and related structures shall conform to Practice E1583, or shall be recognized for lead analysis as promulgated by authorities having jurisdiction, or both.

NOTE 2—In the United States of America, laboratories performing analysis of samples collected during lead-based paint activities are required to be accredited to ISO/IEC 17025 and to other requirements promulgated by the Environmental Protection Agency (EPA).

5.3 This test method may also be used to analyze similar samples from other environments such as toxic characteristic extracts of waste sampled using Guide E1908, and soil and sludge as prepared for analysis using U.S. EPA SW-846 Test Method 1311.

6. Interferences

6.1 In FAAS, the occurrence of interferences is less common than in many other analytical techniques. Interferences can occur, however, and when encountered are corrected as indicated in the following sections. The known interferences and correction methods for lead are indicated in Table 2. The methods of standard additions and background monitoring and correction (2-5) are used to identify the presence of an interference. Insofar as possible, the matrix of sample and standard are matched to minimize possible interference.

6.2 Background or nonspecific absorption can occur from particles produced in the flame, which can scatter light and produce an apparent absorption signal. Light scattering may be encountered when solutions of high salt content are being analyzed. They are most severe when measurements are made at shorter wavelengths (for example, below about 250 nm). Background absorption may also occur as the result of the formation of various molecular species which can absorb light. The background absorption can be accounted for by the use of background correction techniques (2).

6.3 Spectral interferences are those interferences which result from an atom different from the one being measured that absorbs a portion of the radiation. Such interferences are extremely rare in FAAS. In some cases, multi-element hollow cathode lamps may cause a spectral interference by having closely adjacent emission lines from two different elements. In general, the use of multi-element hollow cathode lamps is discouraged.

6.4 Ionization interference occurs when easily ionized atoms are being measured. The degree to which such atoms are ionized is dependent upon the atomic concentration and the presence of other easily ionized atoms. This interference can be

controlled by the addition of a high concentration of another easily ionized element which will buffer the electron concentration in the flame.

6.5 Chemical interferences occur in FAAS when species present in the sample cause variations in the degree to which atoms are formed in the flame, or when different valence states of a single element have different absorption characteristics. Such interferences may be controlled by adjusting the sample matrix or by the method of standard additions (3). Also, the use of lanthanum as a releasing element minimizes the interference from the formation of nonvolatile compounds in the flame. Lanthanum forms nonvolatile compounds preferentially with the interferent so that the analyte remains free.

6.6 Physical interferences may result if the physical properties of the samples vary significantly. Changes in viscosity and surface tension can affect the sample aspiration rate and thus cause erroneous results. Sample dilution or the method of standard additions, or both, are used to correct such interferences. High concentrations of silica in the sample can cause aspiration problems. If large amounts of silica are extracted from the samples, they shall be allowed to stand for several hours and centrifuged or filtered to remove the silica.

6.7 This procedure references matrix-specific methods for sample preparation.

7. Apparatus

7.1 Analytical Apparatus:

7.1.1 *Flame Atomic Absorption Spectrophotometer*, equipped with air/acetylene burner head.

7.1.2 *Lead (Pb) Hollow Cathode or Electrodeless Discharge Lamp*.

7.1.3 *Deuterium Continuum Lamp*.

7.1.4 *Compressed Air*—Appropriate pressure-reducing regulator with base connections (see instrument manufacturer's instructions).

7.1.5 *Acetylene Gas and Regulator*—A cylinder of acetylene equipped with a two-gauge, two-stage pressure-reducing regulator with hose connections (see instrument manufacturer's instructions).

7.1.6 *Beakers*, Phillips or Griffin, 125 mL, borosilicate glass.

7.1.7 *Centrifuge Tubes*, 15 mL, graduated, plastic or borosilicate glass; or, tubes to fit the autosampler in use.

7.1.8 *Miscellaneous Borosilicate Glassware (Pipets and Volumetric Flasks)*—All pipets and volumetric flasks shall be calibrated Class A volumetric glassware.