Designation: ~~E2119 – 16~~ E2119 – 20

Standard Practice for Quality Systems for Conducting In Situ Measurements of Lead Content in Paint or Other Coatings Using Field-Portable X-Ray Fluorescence (XRF) Devices[1]

This standard is issued under the fixed designation E2119; 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 practice covers the collection and documentation of quality control (QC) measurements for determining acceptable levels of instrumental performance when using field-portable energy-dispersive ~~x-ray~~X-ray fluorescence spectrometry devices (XRFs) for the purposes of generating lead classification results from measurements on paint and other coating films within buildings and related structures.

1.1.1 This practice is not designed to determine the presence of a hazard as defined by authorities having jurisdiction in the United States or other jurisdictions. See Guide E2115 and the HUD Guidelines for more information.

1.2 QC procedures covered in this provisional practice include the performance of calibration checks, substrate bias checks, and specific instructions for documenting the collected data for later use in reporting the results.

1.3 No detailed operating instructions are provided because of differences among the various makes and models of suitable instruments. Instead, the analyst is to follow the instructions provided by the manufacturer of the particular XRF device or other relevant sources of information on XRF operation.

1.4 This practice contains notes which are explanatory and are not part of the mandatory requirements of this provisional practice.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this 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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory ~~requirements~~limitations prior to use.*

1.7 *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.*

[1] This practice is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.12 on Sampling and ~~Analysis,~~Analysis of ~~Lead,~~Lead for Exposure and Risk Assessment.

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

~~E1583~~D1356 ~~Practice for Evaluating Laboratories Engaged in Determination of Lead in Paint, Dust, Airborne Particulates, and Soil Taken From and Around Buildings and Related Structures~~Terminology Relating to Sampling and Analysis of Atmospheres

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~~

E1645 Practice for Preparation of Dried Paint Samples by Hotplate or Microwave Digestion for Subsequent Lead Analysis

E1729 Practice for Field Collection of Dried Paint Samples for Subsequent Lead Determination

E2115 Guide for Conducting Lead Hazard Assessments of Dwellings and of Other Child-Occupied Facilities

E3193 Test Method for Measurement of Lead (Pb) in Dust by Wipe, Paint, and Soil by Flame Atomic Absorption Spectrophotometry (FAAS)

E3203 Test Method for Determination of Lead in Dried Paint, Soil, and Wipe Samples by Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES)

2.2 ~~*HUD Document:*~~*Other Documents:*

40 CFR 745 Lead-Based Paint Poisoning Prevention in Certain Residential Structures[3]

HUD Guidelines Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing, 2nd Edition, July 2012[4]

3. Terminology

3.1 *Definitions*—For definition of terms not presented below, refer to ~~Terminology~~Terminologies D1356 and E1605.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *building component, n*—part or element of a building that is made of an industry product that is manufactured as an independent unit and is capable of being joined with other elements. ~~Examples include doors, walls, baseboard and exterior siding.~~

3.2.1.1 *Discussion—*
Examples include doors, walls, baseboard and exterior siding.

3.2.2 *calibration check, n*—a procedure that generates a QC measurement using a calibration test sample with one type of control block (usually wood).

3.2.3 *calibration mode, n*—a selected operating mode that permits adjustment of an instrument's calibration.

3.2.4 *calibration test sample, n*—a test film sample of a known lead level in mg/cm^2~~,~~ which ~~must have~~ has a reported uncertainty of the lead ~~level. Calibration test samples may be separate from a substrate or adhered to a substrate. All calibration test samples shall be~~ level traceable to the National Institute of Standards and Technology (NIST) ~~standard reference materials~~ Standard Reference Materials (SRMs) or other national or international standard reference materials ~~and~~that have a known specified uncertainty ~~in~~for the known lead level.

3.2.4.1 *Discussion—*
For example, use of SRM 2579a, Lead Paint Films for Building Surfaces (SRM 2570 through SRM 2575), is required in the United States when conducting lead-based paint inspections.

3.2.4.2 *Discussion—*
Calibration test samples may be separate from a substrate or adhered to a substrate.

3.2.5 *continuing calibration check, n*—a calibration check performed during the testing day after the initial calibration check. A continuing calibration check also can serve as a final calibration check.

3.2.6 *control block, n*—a small block of material of an identifiable substrate type used to simulate a building material during QC measurements.

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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.

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

[4] Available from U.S. Department of Housing and Urban Development, 451 7th Street, SW, Washington, DC 20410, http://www.hud.gov.

3.2.7 *display unit, n*—an electronic device that presents the results of an XRF measurement to the user. Other parameters such as total measurement time also may be presented.

3.2.8 *final calibration check, n*—the last calibration check performed in a testing period.

3.2.9 *inconclusive lead classification result, n*—a lead classification result that reliably cannot be expressed, for example, reported, as either containing lead (positive) or not containing lead (negative) at or above an appropriate local, state, or federal action level for lead in coatings. ~~Such results commonly are referred to and reported as "inconclusive" results, for example, the XRF measurement that cannot determine whether lead is or is not present at or above an appropriate local, state, or federal action level for lead in coatings.~~

3.2.10 *initial calibration check, n*—the first calibration check of the testing period performed after the XRF instrument has been turned on and allowed to warm up.

3.2.11 *lead classification result, n*—an XRF measurement expressed, for example, as either positive-for-lead, or negative-for-lead, at or above and appropriate local, state, or federal action level for lead in coatings. ~~A negative-for-lead result does not mean there is no lead present. For some makes and models of XRF instruments, lead measurement values obtained near an appropriate local, state or federal action level for lead in coatings may generate inconclusive lead classification results.~~

3.2.11.1 *Discussion—*
A negative-for-lead result does not mean there is no lead present.

3.2.11.2 *Discussion—*
For some makes and models of XRF instruments, lead measurement values obtained near an appropriate local, state or federal action level for lead in coatings may generate inconclusive lead classification results.

3.2.12 *nominal read time, n*—a read time that results when the radioactive source normally provided by the manufacturer for that XRF instrument is at its original source strength.

3.2.13 *performance characteristic sheet (PCS), n*—defines acceptable operating specifications and procedures for a specific XRF lead-based paint analyzer as determined by the HUD for use in housing in the United States.

3.2.13.1 *Discussion—*
If an XRF analyzer does not have a PCS, or if it is not used, or if the data are not analyzed in accordance with its PCS, the actions and results are not recognized for hazard determinations in housing in the United States.

3.2.14 *operating mode, n*—one or more settings that define the operating parameters of an XRF instrument. Some XRF instruments have multiple settings for use under different testing situations, for example, substrates, time or testing objectives.

3.2.15 *power-down, n*—an event where the power to the XRF instrument is turned off. The XRF instrument can not collect and display any XRF measurements after a power-down.

3.2.16 *power-on, n*—an event where the power to the XRF instrument from the battery is turned on. The XRF instrument can collect and display any XRF measurements after a power-on.

3.2.17 *probe, n*—a hand-held device containing a radioactive source, ~~x-ray~~X-ray detector and associated mechanical and electronic components that is placed against a test location or calibration test sample to obtain an XRF measurement.

3.2.18 *radioactive source, n*—a radioactive material (for example, ^{57}Co or ^{109}Cd) that emits ~~X rays~~ X-rays or gamma rays that cause ionization of atoms in the sample, and subsequently a cascade of higher energy electrons into the vacated lower energy shells. ~~As these electrons fall into the lower energy orbitals, X rays characteristic of the atomic species, such as lead, are emitted from the test location.~~

3.2.18.1 *Discussion—*
As these electrons fall into the lower energy orbitals, X-rays characteristic of the atomic species, such as lead, are emitted from the test location.

3.2.19 *read time*—a period of ~~X ray~~ X-ray data collection ~~time. It may be~~ time controlled manually or automatically depending on the XRF instrument model. ~~It begins with the opening of the XRF instrument shutter to expose the paint film surface to source gamma rays and X rays and ends when the source shutter is closed and the XRF reading is complete.~~

3.2.19.1 *Discussion—*
The read time begins with the opening of the XRF instrument shutter to expose the paint film surface to source gamma rays and X-rays, and ends when the source shutter is closed and the XRF reading is complete.

3.2.20 *sampling site*—a local geographical area that contains at least one unit being tested. A sampling site generally is limited to an area that is easily covered by walking.

3.2.21 *substrate, n*—the building material that lies under the coating.

3.2.22 *substrate bias check (SBC), n*—a procedure that generates a QC measurement using a calibration test sample and a control block to determine the effect of that substrate on the XRF measurement.

3.2.23 *substrate-corrected XRF measurements*—a procedure that corrects an XRF measurement for substrate effects (see the HUD Guidelines for more information on substrate corrections).

3.2.24 *substrate type, n*—the type of building material that lies under the coating. Examples include wood, plaster, gypsum wallboard, metal, brick, and concrete.

3.2.25 *test location, n*—an area on a building component where a lead measurement value is obtained.

3.2.26 *testing period, n*—a block of time that defines the continuous power-on operation of an XRF instrument. Any power-down of an XRF instrument terminates the testing period.

3.2.27 *unit, n*—all or a portion of a structure or facility that is the target of an investigation. ~~Test locations are considered to be within a unit. An example of a unit is a single family dwelling including a detached garage that is part of the property.~~

3.2.27.1 *Discussion—*
Test locations are considered to be within a unit. An example of a unit is a single family dwelling including a detached garage that is part of the property.

3.2.28 ~~*x-ray*~~*X-ray detector, n*—a device that results in an electronic signal as a result of the interception of an ~~x-ray.~~ X-ray. Examples include gas proportional counters, for example, Xe, solid scintillation counters, for example, CsI, and semiconductor devices of elemental composition, for example, Si or Ge, or compound composition, for example, HgI_2, CdTe, or CdZnTe.

3.2.29 *XRF instrument, n*—a field-portable XRF device or analyzer with associated equipment designed and manufactured for use in measuring lead in paint or other coating films. ~~XRF instruments, at minimum, include an excitation source, such as a radioactive source, x-ray detector, probe, and a display unit.~~

3.2.29.1 *Discussion—*
XRF instruments, at minimum, include an excitation source, such as a radioactive source, X-ray detector, probe, and a display unit.

3.2.30 *XRF measurement, n*—a procedure used to determine the lead content of a coating at a test location using an XRF instrument, or a lead result, expressed as mg of lead per cm^2 of surface, that is, mg/cm^2, obtained from a coating at a test location using an XRF instrument. ~~An XRF measurement may be one reading or the average of one or more XRF readings.~~

3.2.30.1 *Discussion—*
An XRF measurement may be one reading or the average of one or more XRF readings.

3.2.31 *XRF reading, n*—a response, expressed as mg of lead/cm^2 of surface, that is, mg/cm^2, of an XRF instrument for one read time.

4. Summary of Practice

4.1 This practice covers the quality assurance (QA), ~~quality control (QC),~~ QC, and recording procedures to follow when using field-portable energy-dispersive x-rayX-ray fluorescence spectrometry devices (XRFs) to collect measurements of lead in paint or lead in other coating films for the purposes of generating lead classification results. This practice includes start-up procedures, beginning-of-day calibration check QC procedures, during-the-test-day QC check procedures, and end-of-day QC check procedures designed to complement standard operating procedures written by manufacturers for specific models of field-portable XRF instruments.

5. Significance and Use

5.1 This practice provides procedures to generate and document QC data for ensuring that an XRF is operating within acceptable tolerances throughout the testing period when being used to collect lead results during a lead-based painpaint (LBP) inspection for the purposes of generating lead classification results.

5.2 This practice is intended to supplement XRF instrument manufacturer protocols and Performance Characteristic Sheets (PCSs)PCSs[4] through the use of QA and QC procedures to provide uniform lead testing practices among the wide variety of available field-portable XRF instruments.

NOTE 1—In the United States, an XRF used to perform a lead-based paint inspection shall be utilized according to the PCS for the particular instrument model in use.

5.3 While the QC results collected using this practice can provide assurances that an XRF instrument is operating within acceptable tolerances, this practice does not determine an actual level of confidence for a classification result obtained from an XRF measurement.

5.4 This practice does not address selection of test locations or representative sampling for leaded paint. Additional information on conducting measurements of lead in leaded paint or other coatings may be found in Guide E2115 and the HUD Guidelines, Chapter 7.

5.5 This practice involves the use of field-portable XRF instruments that may contain radioactive materials that emit X rays X-rays and gamma rays. These instruments are intended for use only by qualified, trained personnel.

5.6 The use of field-portable XRF instruments for measurement of lead may not accurately reveal low but still potentially hazardous levels of lead.

6. Materials and Equipment

6.1 *(Field-Portable) XRF Instrument*—One of a variety of the commercially available field-portable XRF instruments designed for use in measuring lead in paint and other coatings.

6.2 *Calibration Check Samples*—Calibration test samples that are used to verify XRF instrument calibration.

6.3 *Control Blocks*—A set of substrate materials for use in making QC measurements as defined in Table 1.

6.4 *Substrate Support*—A support material used to hold calibration check samples and control blocks away from any additional underlying material in a manner that will not interfere with the lead measurements on calibration check samples. The support material shall not itself have potentially interfering leaded paint or other material within or on it and shall be one of the following:

6.4.1 A polystyrene foam block with minimum thickness of 25 cm,

6.4.2 A table constructed from an empty cardboard box with minimum height of 25 cm, or

6.4.3 Any physical arrangement that holds the calibration check sample so that at least 25 cm of free air space or foam material exists between the XRF instrument-sample-substrate arrangement and any nearby physical objects.

7. Procedure

NOTE 2—It is highly recommended that a room inventory or testing preplan be performed and documented either of the entire unit or of each room prior

TABLE 1 Specifications for Control Blocks[A]

Control Block Substrate Material	Substrate Materials Represented by Control Block	Minimum Thickness of Control Block[B]
Control Block Substrate Material	Substrate Materials Represented by Control Block	Minimum Thickness of Control Block[B]
Wood, clear pine	All wood and wallboard materials	17 mm
Steel (316 stainless)[C]	All metal materials	6 mm
Metal (316 stainless)[C]	All metal materials	6 mm
Brick	All plaster, poured concrete, pressed concrete, and brick materials	50 mm

[A] Other materials can be used to supplement this list. However, it is the responsibility of the user to properly characterize other control block materials.

[B] All control blocks are to have minimum length and width dimensions of 60 mm by 60 mm.

[C] This grade of steel has been selected because it is readily available and impervious to rusting. Although this steel is not representative of the types of painted or coated metals commonly found in buildings and related structures, it will serve to provide a satisfactory surrogate for quality control measurements. Carbon steel is susceptible rusting but is a more common coated building material in housing, commercial and steel structures components. Although rust preventing in nature, 316 grade stainless steel may be more difficult to locate and is typically not coated in "real world" applications.

to testing. Such is useful to assure that no test locations of interest be inadvertently omitted. See the HUD Guidelines, Chapter 7, for further information.

7.1 Conduct XRF measurements on test locations in accordance with manufacturer protocols (see Note 12). In addition, XRF measurements shall adhere to the items presented in 7.27.2 – 7.4.3-7.4.3.

NOTE 3—Exercise care to avoid performing XRF measurements on surfaces, which may generate inaccurate results even under conditions where all measurements are performed within the QC and QA specifications described in this practice. Surfaces that may generate inaccurate results include:

(1) Extremely rough, curved or highly ornate surfaces. In general, field-portable XRF instruments are designed to perform XRF measurements on flat surfaces. Any surface condition that does not permit the XRF probe to come into complete contact with the surface may generate inaccurate results.

(2) Substrates that have leaded coatings on the side opposite from the surface being measured. The extent of the effect on an XRF measurement depends on the instrument model, the substrate type and thickness, and radioactive source type and intensity, and the lead content of the film on the opposite side. An example would be a recessed portion of a thin panel door where one side contains a leaded coating while the other side does not. In this example, measurements on the side without the leaded coating side may be biased high because of read-through from the lead in the coating on the opposite side.

(3) Surfaces that are likely to have objects that may interfere with the XRF measurement, such as pipes or electrical wires, wires near electrical breaker panels or load centers, lying immediately under or very near the test location.

7.2 *Warm-Up of XRF Instruments*—All XRF instruments shall be allowed to warm up prior to making any XRF measurements. measurements according to manufacturer's instructions. In absence of specific instructions from the manufacturer, expend a minimum of 5 min between the time an XRF instrument is turned on to the time that XRF instrument is used to perform XRF measurements.

7.3 *Identification of Test Locations*—Each XRF measurement shall be uniquely identified and recorded. Identification shall be such that a given XRF measurement can be uniquely associated with only one test location or control block measurement. If a measurement is the average of more than one XRF reading, each XRF reading included in the average shall be uniquely identified and recorded. See Section 8 on record keeping.

7.4 *Quality Control (QC) Checks*—Perform QC checks as specified below:

7.4.1 *QC Calibration Checks*—Perform calibration checks as specified in Table 2 for each operating mode used during the testing period (see Note 24). If more than one operating mode is used during a testing period, then replicate QC calibration checks, as specified in Table 2, for each of the different calibration modes using a control block substrate type that is appropriate for the operating mode are required. Depending on the make and model of the XRF instrument, different operating modes may be specified by the manufacturer on different substrate types.

NOTE 4—Depending on the make and model of the XRF instrument, different operating modes may be specified by the manufacturer for different substrate

TABLE 2 Specifications for Performing Calibration Checks

Item	Specification	
Item	Specification	
Frequency of QC checks	1. Perform an initial calibration check after power-on allowing for an appropriate warm-up period per the manufacturer instructions. Frequency of QC checks	(*1*) Perform a
2. Following the initial calibration check, perform a continuing calibration check every 2 h or less. (*2*) Following the initial calibration check, perform a continuing calibration check every 2 h or less.		
3. After making XRF measurements at test locations and prior to power-down of the XRF instrument, perform a final continuing calibration check. All XRF measurements at test locations within the testing period must be bracketed by an initial and a final continuing calibration check. Automatic shut-down of XRF instruments resulting from excessive battery drainage may not be predicted with accuracy. Therefore, replacement of a battery or any brief loss of power during the testing period shall not be considered as a power-down event. However, any battery pack replacement shall be immediately followed by a continuing or final calibration check (see Note). (*3*) After making XRF measurements at test locations and prior to power-down of the XRF instrument, perform a final continuing calibration check. All XRF measurements at test locations within the testing period must be bracketed by an initial and a final continuing calibration check. Automatic shut-down of XRF instruments resulting from excessive battery drainage may not be predicted with accuracy. Therefore, replacement of a battery or any brief loss of power during the testing period shall not be considered as a power-down event. However, any battery pack replacement shall be immediately followed by a continuing or final calibration check (see Note).		
	Note—It is recommended that if battery loss can be predicted, that calibration checks should be collected prior to a battery replacement since the degree of power loss required to push an XRF instrument out of tolerance, prior to automatic shutdown the XRF instrument caused by battery loss, is unknown.	
Nominal Read Time or Operating Mode, or both	The nominal read time or operating mode, or both, shall be that recommended by the manufacturer for an XRF measurement. The nominal read time or operating mode used for test locations shall be the same as that used for calibration checks.	
Number of Replicates	A minimum of one XRF measurements shall be taken on each calibration check sample having a different lead level. Compare this measurement to the error tolerance.	