Designation: C1726/C1726M − 10 (Reapproved 2018)

Standard Guide for Use of Modeling for Passive Gamma Measurements[1]

This standard is issued under the fixed designation C1726/C1726M; 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 guide addresses the use of models with passive gamma-ray measurement systems. Mathematical models based on physical principles can be used to assist in calibration of gamma-ray measurement systems and in analysis of measurement data. Some nondestructive assay (NDA) measurement programs involve the assay of a wide variety of item geometries and matrix combinations for which the development of physical standards are not practical. In these situations, modeling may provide a cost-effective means of meeting user's data quality objectives.

1.2 A scientific knowledge of radiation sources and detectors, calibration procedures, geometry and error analysis is needed for users of this standard. This guide assumes that the user has, at a minimum, a basic understanding of these principles and good NDA practices (see Guide C1592/C1592M), as defined for an NDA professional in Guide C1490. The user of this standard must have at least a basic understanding of the software used for modeling. Instructions or further training on the use of such software is beyond the scope of this standard.

1.3 The focus of this guide is the use of response models for high-purity germanium (HPGe) detector systems for the passive gamma-ray assay of items. Many of the models described in this guide may also be applied to the use of detectors with different resolutions, such as sodium iodide or lanthanum halide. In such cases, an NDA professional should determine the applicability of sections of this guide to the specific application.

1.4 Techniques discussed in this guide are applicable to modeling a variety of radioactive material including contaminated fields, walls, containers and process equipment.

1.5 This guide does not purport to discuss modeling for "infinite plane" in situ measurements. This discussion is best covered in ANSI N42.28.

1.6 This guide does not purport to address the physical concerns of how to make or set up equipment for in situ measurements but only how to select the model for which the in situ measurement data is analyzed.

1.7 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.8 *The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.*

1.9 *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]

C1490 Guide for the Selection, Training and Qualification of Nondestructive Assay (NDA) Personnel

C1592/C1592M Guide for Making Quality Nondestructive Assay Measurements (Withdrawn 2018)[3]

C1673 Terminology of C26.10 Nondestructive Assay Methods

2.2 *Other Standard:*[4]

ANSI N42.28 Performance Standard for the Calibration of Germanium Detectors for In Situ Gamma-Ray Measurements

3. Terminology

3.1 See Terminology C1673.

---

[1] This guide is under the jurisdiction of ASTM Committee C26 on Nuclear Fuel Cycle and is the direct responsibility of Subcommittee C26.10 on Non Destructive Assay.

Current edition approved April 1, 2018. Published May 2018. Originally approved in 2010. Last previous edition approved in 2010 as C1726/C1726M – 10. DOI: 10.1520/C1726_C1726M-10R18.

[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.

4. Summary of Guide

4.1 Passive gamma-ray measurements are applied in conjunction with modeling to nondestructively quantify radioactivity.

4.1.1 Modeling may be used to *(1)* design and plan the measurements, *(2)* establish instrument calibration, *(3)* interpret the data acquired, *(4)* quantify contributions to the measurement uncertainty, *(5)* simulate spectra, and *(6)* evaluate the effectiveness of shielding.

4.1.2 Various models commonly use analytical, numerical integration and radiation transport approaches. This guide provides a brief review of several approaches to help the user select a suitable method and apply that method appropriately.

4.1.3 Modeling makes use of knowledge of the measurement configuration including the shape, dimensions and materials of the detector, collimator, and measurement item content.

4.1.4 The exact geometry may be approximated in the model. The degree of approximation acceptable is assessed on a case by case basis.

4.1.5 Process knowledge may be required to provide information about inner containers, intervening absorbers, matrix materials or which radionuclides are present.

4.1.6 The models make use of basic physical interaction coefficients. Libraries and data sets must be available.

4.1.7 Models are typically used to: *(1)* account for field of view and geometry effects, *(2)* account for matrix attenuation, *(3)* account for container wall and other absorbers, *(4)* model detectors, *(5)* transfer calibrations from one configuration to another, *(6)* bound the range of assay values due to variations in modeling representation parameters, *(7)* iteratively refine assessments and decision making based on comparisons with observations.

4.1.8 Scans may be performed using low-resolution, portable gamma-ray detectors (for example, NaI) to identify the location of activity and assist with the modeling.

4.1.9 Measurement uncertainties are estimated based on uncertainties of the assumptions of the model.

5. Significance and Use

5.1 The following methods assist in demonstrating regulatory compliance in such areas as safeguards (Special Nuclear Material), inventory control, criticality control, decontamination and decommissioning, waste disposal, holdup and shipping.

5.2 This guide can apply to the assay of radionuclides in containers, whose gamma-ray absorption properties can be measured or estimated, for which representative certified standards are not available. It can be applied to in situ measurements, measurement stations, or to laboratory measurements.

5.3 Some of the modeling techniques described in the guide are suitable for the measurement of fall-out or natural radioactivity homogenously distributed in soil.

5.4 Source-based efficiency calibrations for laboratory geometries may suffer from inaccuracies due to gamma rays being detected in true coincidence. Modeling can be an advantage since it is unaffected by true coincidence summing effects.

6. Procedure

6.1 Modeling may lead to a bias if any of the measurement parameters do not match the physical characteristics of the item. Uncertainties in the item parameters of the following may lead to a bias:

6.1.1 Matrix distribution is homogenous throughout the container,
6.1.2 Hidden containers,
6.1.3 Matrix identification,
6.1.4 Container fill heights,
6.1.5 Mass attenuation coefficients,
6.1.6 Matrix density,
6.1.7 Detector parameters, and
6.1.8 Physical distribution of radioactivity.

6.2 If the quantity of nuclear material is "infinitely thick" to the emitted gamma rays, measurement results will be biased. This hazard is common when measuring items containing large quantities of heavy elements (for example, thorium, uranium, or plutonium) or items with highly attenuating matrices. Alternate NDA assay methods are recommended if this condition exists.

6.3 Self attenuation, commonly present in lumps of actinide material, will bias results low unless lump corrections are computed.

6.4 The Generalized Geometry Holdup Method must be calibrated with the collimator attached to the detector. If the detector recess changes from the calibration position, the results will be biased.

6.5 Absorber foils that are used to reduce count rate must be included in the model.

6.6 Attenuation corrections for very thick items may be somewhat compromised by coherent scattering, which may not be accurately modeled by attenuation calculations.

7. Method Descriptions

Five commonly used methods are described. These include: *(1)* Generalized Geometry Holdup, *(2)* Far-field Approximation, *(3)* Voxel Intrinsic Efficiency, *(4)* Radiation Transport Code, and *(5)* Hybrid Monte Carlo.

7.1 *Generalized Geometry Holdup*—The method represents items as a point, line, or area (**1**).[5] Three method calibrations are obtained from one set of calibration measurements. Point sources of the same material as that to be measured are often used for the calibration. Measurements and calibrations are made with a collimator attached. Additional attenuation correction factors are needed for a complete analysis. The detector calibrations remain the same for all measurements, but attenuation correction factors will vary with the specific measurement. Results are typically reported in units of mass.

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