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Standard Guide for Making Quality Nondestructive Assay Measurements[1]

This standard is issued under the fixed designation C1592/C1592M; 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 is a compendium of Quality Measurement Practices for performing measurements of radioactive material using nondestructive assay (NDA) instruments. The primary purpose of the guide is to assist users in arriving at quality NDA results, that is, results that satisfy the end user's needs. This is accomplished by providing an acceptable and uniform basis for the collection, analysis, comparison, and application of data. The recommendations are guidelines to achieving quality NDA measurements in most areas.

1.2 This guide applies to the use of NDA instrumentation for the measurement of nuclear materials by the observation of spontaneous or stimulated nuclear or atomic radiations, including photons, neutrons, or heat. Recommended calibration, operating, and assurance methods represent guiding principles based on current NDA technology. The diversity of industry-wide nuclear materials measurement applications and instrumentation precludes discussion of specific measurement situations. As a result, compliance with practices recommended in this guide must be based on a thorough understanding of contributing variables and performance requirements of the specific measurement application.

1.3 Selection of the best instrument for a given measurement application and advice on the use of this instrument must be provided by a qualified NDA professional following guidance provided in Guide C1490. This guide is to be used as a reference, and to supplement the critical thinking, professional skill, expert judgment, and experimental test and verification needed to ensure that the instrumentation and methods have been properly implemented.

1.4 The intended audience for this guide includes but is not limited to Management, Auditor Support, NDA Qualified Instrument Operators, NDA Technical Specialists, and NDA Professionals.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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, health, and environmental practices and determine the applicability of regulatory 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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C986 Guide for Developing Training Programs in the Nuclear Fuel Cycle (Withdrawn 2001)[3]

C1009 Guide for Establishing and Maintaining a Quality Assurance Program for Analytical Laboratories Within the Nuclear Industry

C1030 Test Method for Determination of Plutonium Isotopic Composition by Gamma-Ray Spectrometry

C1068 Guide for Qualification of Measurement Methods by a Laboratory Within the Nuclear Industry

C1128 Guide for Preparation of Working Reference Materials for Use in Analysis of Nuclear Fuel Cycle Materials

C1133/C1133M Test Method for Nondestructive Assay of Special Nuclear Material in Low-Density Scrap and Waste by Segmented Passive Gamma-Ray Scanning

C1156 Guide for Establishing Calibration for a Measurement Method Used to Analyze Nuclear Fuel Cycle Materials

C1207 Test Method for Nondestructive Assay of Plutonium in Scrap and Waste by Passive Neutron Coincidence Counting

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[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.

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

C1210 Guide for Establishing a Measurement System Quality Control Program for Analytical Chemistry Laboratories Within Nuclear Industry
C1215 Guide for Preparing and Interpreting Precision and Bias Statements in Test Method Standards Used in the Nuclear Industry
C1221 Test Method for Nondestructive Analysis of Special Nuclear Materials in Homogeneous Solutions by Gamma-Ray Spectrometry
C1297 Guide for Qualification of Laboratory Analysts for the Analysis of Nuclear Fuel Cycle Materials
C1254 Test Method for Determination of Uranium in Mineral Acids by X-Ray Fluorescence
C1268 Test Method for Quantitative Determination of ^{241}Am in Plutonium by Gamma-Ray Spectrometry
C1316 Test Method for Nondestructive Assay of Nuclear Material in Scrap and Waste by Passive-Active Neutron Counting Using ^{252}Cf Shuffler
C1455 Test Method for Nondestructive Assay of Special Nuclear Material Holdup Using Gamma-Ray Spectroscopic Methods
C1458 Test Method for Nondestructive Assay of Plutonium, Tritium and ^{241}Am by Calorimetric Assay
C1490 Guide for the Selection, Training and Qualification of Nondestructive Assay (NDA) Personnel
C1493 Test Method for Non-Destructive Assay of Nuclear Material in Waste by Passive and Active Neutron Counting Using a Differential Die-Away System
C1500 Test Method for Nondestructive Assay of Plutonium by Passive Neutron Multiplicity Counting
C1514 Test Method for Measurement of ^{235}U Fraction Using Enrichment Meter Principle
C1592 Guide for Making Quality Nondestructive Assay Measurements
C1673 Terminology of C26.10 Nondestructive Assay Methods
C1718 Test Method for Nondestructive Assay of Radioactive Material by Tomographic Gamma Scanning
C1726/C1726M Guide for Use of Modeling for Passive Gamma Measurements
C1807 Guide for Nondestructive Assay of Special Nuclear Material (SNM) Holdup Using Passive Neutron Measurement Methods
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E181 Test Methods for Detector Calibration and Analysis of Radionuclides
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E1323 Guide for Evaluating Laboratory Measurement Practices and the Statistical Analysis of the Resulting Data
E1488 Guide for Statistical Procedures to Use in Developing and Applying Test Methods

2.2 *ANSI Standards:*[4]

ANSI N15.36 Methods Of Nuclear Material Control - Measurement Control Program - Nondestructive Assay Measurement Control And Assurance
ANSI N15.5 Statistical Terminology and Notation for Nuclear Materials Management

2.3 *Other Documents:*

ESARDA NDA Good Practices Guide[5]
NPL Good Practices Guide[6]

3. Terminology

3.1 Definitions presented here are confined to those terms not defined in Terminology C1673, other common nuclear materials glossaries/references or whose use is specific to this application.

3.2 *Definitions:*

3.2.1 *differential die away technique (DDT), n*—also referred to as DDA, an NDA technique for characterizing fissionable material in scrap and waste using prompt neutrons from fissions induced by neutron generator interrogation source.

3.2.2 *in-process material, n*—the nuclear material in a process stream, excluding holdup.

3.2.3 *passive neutron coincidence counting, n*—a technique used to measure the rate of temporally coincident neutron emission in the assay item.

3.2.4 *Poisson assumption, n*—for counting measurements, it is assumed that the net counts in a fixed period of time follow a Poisson distribution; this assumption can be verified by comparing the observed standard deviation of a series of measurements on an item with the square root of the average number of counts; if the Poisson assumption is correct, these numbers should be equal within statistical uncertainty.

3.2.5 *procedure, n*—a set of systematic instructions for using a method of measurement or of the steps associated with the method.

3.2.6 *qualitative analysis, n*—an analysis or measurement in which some or all of the attributes or characteristics of an item are determined, but no quantitative estimates of the radionuclides are made.

3.2.7 *quality measurement practice, n*—an acceptable way to perform some operation associated with a specific measurement technique that is known or believed to influence the quality of a measurement (a way to perform some operation associated with a specific NDA technique in a manner that meets the quality requirements of a measurement).

3.2.8 *radioactive emissions, n*—alpha, beta, gamma-ray, x-ray, and neutron emissions from spontaneous fission, induced fission, or delayed neutron emission following beta decay.

3.2.9 *replicate, n*—one of several identical experiments, procedures, or samples; it is the general case for which duplicate and triplicate, consisting of two and three measurements, respectively, are the special cases.

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

[5] Available from ESARDA Secretariat c/o European Commission JRC Bldg. 42A Via E. Fermi, 2749 21027-Ispra (VA), Italy, https://esarda.jrc.ec.europa.eu.

[6] Available from National Physical Laboratory, Hampton Road, Teddington, Middlesex, TW11 0LW, https://www.npl.co.uk.

3.2.10 *segmented gamma scanner, n*—an NDA technique used to measure the gamma-ray emissions from low-density scrap and waste packaged in cylindrical containers; the technique involves independent measurements of the vertical segments of the container and may incorporate corrections for count rate losses and matrix attenuation.

3.2.11 *shift-register-based coincidence circuit, n*—a dedicated electronic circuit for measuring temporally correlated quantitities relevant to passive neutron coincidence counting.

3.2.12 *shuffler, n*—an NDA technique for characterizing the delayed neutrons from fissionable nuclides in scrap and waste using delayed neutrons induced by ^{252}Cf interrogation source.

3.2.13 *verification, n*—an evaluation of the critical item characteristics to ensure the collected characterization data represents the true characteristics of the sample population to an acceptable degree of accuracy and precision.

4. Significance and Use

4.1 NDA measurement practices aimed at achieving quality results are described in this guide. The application of the material provided in this guide should be determined on a case by case basis. Not all elements are required for all applications.

4.2 Nondestructive assay measurements are typically performed when the items measured or goals of the measurement program favor or require NDA over destructive analysis. NDA is typically favored when collecting a representative sample of the item is difficult or impractical (for example, scrap and waste items), personnel exposure would be significant, spread of contamination from sampling would occur, generation of secondary waste must be minimized, the weight and/or tare weight of the item cannot easily be determined (for example, in place process equipment), rapid turn-around of the measurement results is needed, or the NDA measurement is significantly less expensive than the equivalent destructive analysis.

4.3 The principles provided in this guide should be used to determine which type of measurement is best suited to the measurement application. This determination involves consideration of the characteristics of the items to be measured, as well as the goals of the measurement program.

4.4 This guide applies to the suite of NDA instruments and measurement methods, many of which are described in detail in Refs (**1**) and (**2**).[7] A partial listing of measurement methods and applicable use references is provided in 5.5.1. It is incumbent upon the user to seek additional guidance within ASTM method-specific standards, as this guide does not take precedence. Additional information on specific methods is best found in technical meeting transactions, journals, commercial application notes, and NRC/DOE publications.

4.5 This guide may be applied to many situations spanning the range of nuclear materials from product through waste. Typical applications include: the measurement and characterization of transuranic wastes, low-level wastes, and mixed wastes; the determination of radioactivity below some regulatory threshold, estimated for non-detected radionuclides; the measurement of safeguarded nuclear materials; shipper receiver confirmation; confirmation of nuclear material inventory; support of nuclear criticality safety evaluations; measurement of holdup of special nuclear material in process systems; support of decontamination and decommissioning activities; and in-situ analyses of facilities, glove-boxes, hot cells, and the environment prior to and following demolition.

4.6 When applied to measurement of waste, this guide should be used in conjunction with a waste management plan that segregates the contents of assay items into material categories according to some or all of the following criteria: bulk density of the waste, chemical forms of the radioactive constituents and matrix, (α, *n*) neutron intensity, hydrogen (moderator) and absorber content, geometry, thickness, and distribution of fissile material, and the assay item container size and composition. Each matrix may require a different set of calibration standards and may have different mass calibration limits. The effect on the quality of the assay (that is, maximizing precision and minimizing bias) can significantly depend on the degree of adherence to this waste management plan.

4.7 This guide addresses elements of quality measurement practice such as; nuclear measurement instrumentation and its care; common hazards; facility readiness and requirements to support the NDA equipment; project scoping, requirements and objectives; assembly and deployment of the instrument; calibration and test; computational modeling to augment physical testing; measurement validation; preventive maintenance; and the measurement control program.

5. Quality Measurement Practice

5.1 *Introduction*—NDA measurements of nuclear material are performed to determine the relative or absolute abundance of one or more nuclides. Typically, such a determination is made by comparing the observed response of an unknown amount of material to the response of one or more known standards by means of a functional relationship established by calibration. NDA refers to the qualification and quantification of radionuclides using instrumentation capable of detecting a feature of the radioactive-decay process. These features include such radioactive emissions as alpha, beta, gamma-ray, x-ray, heat, and neutron emissions from spontaneous fission, induced fission, or delayed neutron emission following beta decay. The primary goal of NDA measurements is to arrive at a quality result that satisfies the user's measurement needs without the necessity to alter the item. Adequately analyzing problems and applying appropriate measurement techniques support this goal.

5.2 Each NDA technique has advantages and limitations that must be judged against the specific requirements of the intended applications. No single technique can satisfy all requirements. It is the responsibility of the user to consider the potential problems, and select the proper balance of measurement capability and desired precision and accuracy for the specific application.

5.3 The observed response of an NDA system shows sensitivity to a wide variety of factors that can bias the assay result.

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