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Standard Guide for Nondestructive Assay of Special Nuclear Material (SNM) Holdup Using Passive Neutron Measurement Methods[1]

This standard is issued under the fixed designation C1807; 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 describes passive neutron measurement methods used to nondestructively estimate the amount of neutron-emitting special nuclear material compounds remaining as holdup in nuclear facilities. Holdup occurs in all facilities in which nuclear material is processed. Material may exist, for example, in process equipment, in exhaust ventilation systems, and in building walls and floors.

1.1.1 The most frequent uses of passive neutron holdup techniques are for the measurement of uranium or plutonium deposits in processing facilities.

1.2 This guide includes information useful for management, planning, selection of equipment, consideration of interferences, measurement program definition, and the utilization of resources.

1.3 Counting modes include both singles (totals) or gross counting and neutron coincidence techniques.

1.3.1 Neutron holdup measurements of uranium are typically performed on neutrons emitted during (α, n) reactions and spontaneous fission using singles (totals) or gross counting. While the method does not preclude measurement using coincidence or multiplicity counting for uranium, measurement efficiency is generally not sufficient to permit assays in reasonable counting times.

1.3.2 For measurement of plutonium in gloveboxes, installed measurement equipment may provide sufficient efficiency for performing counting using neutron coincidence techniques in reasonable counting times.

1.4 The measurement of nuclear material holdup in process equipment requires a scientific knowledge of radiation sources and detectors, radiation transport, modeling methods, calibration, facility operations, and uncertainty analysis. It is subject to the constraints of the facility, management, budget, and schedule, plus health and safety requirements, as well as the laws of physics. This guide does not purport to instruct the NDA practitioner on these principles.

1.5 The measurement process includes defining measurement uncertainties and is sensitive to the chemical composition, isotopic composition, distribution of the material, various backgrounds, and interferences. The work includes investigation of material distributions within a facility, which could include potentially large holdup surface areas. Nuclear material held up in pipes, ductwork, gloveboxes, and heavy equipment is usually distributed in a diffuse and irregular manner. It is difficult to define the measurement geometry, identify the form of the material, and measure it.

1.6 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard.

1.7 *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.*

1.8 *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]

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

C1455 Test Method for Nondestructive Assay of Special Nuclear Material Holdup Using Gamma-Ray Spectroscopic Methods

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

[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.

C1592/C1592M Guide for Making Quality Nondestructive Assay Measurements

C1673 Terminology of C26.10 Nondestructive Assay Methods

2.2 *NRC Standard:*

NRC Regulatory Guide 5.23 In-Situ Assay of Plutonium Residual Holdup[3]

2.3 *ANSI Standard:*

ANSI N15.20 Guide to Calibrating Nondestructive Assay Systems[4]

3. Terminology

3.1 *Definitions*—Refer to Terminology C1673 for definitions used in this guide.

4. Summary of Guide

4.1 *Introduction*—Holdup measurements using neutron methods typically measure the (α, n) or spontaneous fission production of neutrons, or both. Neutrons generated in items that do not include significant masses of neutron moderators, such as hydrogenous materials, typically have an escape fraction of nearly one. The isotopic distribution and, for (α, n) production, the chemical composition of the measured material affect assay results and shall be determined by process knowledge or an alternative measurement technique. Ref (**1**)[5] provides an example of a holdup campaign using neutron measurements.

4.2 *Choice of Measurement Method*—Passive neutron measurement methods are typically used for holdup when other methods of measurement (for example, gamma-ray assay) are not practical or would produce large biases. In some cases, neutron measurements are performed in conjunction with gamma-ray measurements for defense in depth or to obtain isotopic information, or both. Neutron measurement instrumentation is typically heavier, more difficult to shield, and has more difficult data interpretation than other NDA measurement methods. Neutrons, though, are very penetrating and less influenced by lumps than gamma rays, and the instrumentation has a very stable response. Examples of when neutron measurements are preferred include containers that severely attenuate gamma rays of interest for the nuclides measured or when sufficient nuclear material is present that self-attenuation of gamma rays of interest is severe (see Test Method C1455 and Guide C1592/C1592M).

4.3 *Specific Neutron Yield*—The number of neutrons generated per unit time per unit mass of the nuclide(s) of interest is an important parameter that is affected by conditions (for example, chemical composition and isotopic distribution) not detectable by passive neutron holdup measurement methods. Information used to estimate specific neutron yield shall be determined using process knowledge or alternate analysis methods (for example, sampling and X-ray fluorescence to determine chemical composition and high-resolution gamma-ray spectroscopy to determine isotopic composition). Both the chemical and isotopic distribution have significant effects on specific neutron yield.

4.4 *Definition of Requirements*—Definition of the holdup measurement requirements should include, as a minimum, the measurement objectives (that is, nuclear criticality safety, special nuclear material (SNM) accountability, radiological safety, or combinations thereof); time and resource constraints; the desired measurement sensitivity, accuracy, and uncertainty; and available resources (schedule, funds, and subject matter experts). Specific data quality objectives should be provided when available.

4.5 *Information Gathering and Initial Evaluation*—Information shall be gathered concerning the item or items to be assayed, and an initial evaluation should be made of the measurement techniques and level of effort needed to meet the holdup measurement requirements. Preliminary radiation measurements may be needed to define the location and extent of the holdup. Additional information should be collected prior to commencement of measurements. This information includes, but is not limited to, the geometric configuration of the item or process equipment to be assayed, location of the equipment in the facility, the presence of neutron moderators and absorbers, neutron leakage multiplication, factors affecting specific neutron yield, sources of background or interferences, facility processing status, radiological and industrial safety considerations, plus the personnel and equipment needed to complete the assay. Sources of information may include a visual survey, engineering drawings, process knowledge, process operators, results of sampling and wet chemical analysis, and prior assay documentation.

4.6 *Measurement Plan*—A measurement plan shall be developed. The initial evaluation provides a basis for choosing the quantitative method and assay model and, subsequently, leads to the determination of the detection system and calibration method to be used. Appropriate reference materials and support equipment are developed or assembled for the specific measurement technique. The plan will include measurement locations and geometries or guidance for their selection. In the plan, required documentation; operating procedures; background measurement methods and frequencies; plus training, quality, and measurement control requirements (Guide C1009) are typically outlined. Necessary procedures, including those for measurement control, shall be developed, documented, and approved.

4.7 *Calibration*—Calibration and initialization of measurement control is completed before measurements of unknowns. Calibration requires reference materials traceable to a National Measurement Institute to establish detection efficiency and modeling detector response to neutron sources. If modeling is used for calibration (for example, Monte Carlo n-Partical (MCNP) modeling), detailed specifications for the detector package will be required. If modeling is used, validation of the calibration shall include validation of each model developed. Familiarity with the facility on which assays will be performed

[3] Available from U. S. Nuclear Regulatory Commission (NRC), One White Flint North, 11555 Rockville Pk., Rockville, MD 20852-2738, http://www.nrc.gov.

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

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