Designation: C1514 – 08 (Reapproved 2017)

Standard Test Method for Measurement of ^{235}U Fraction Using Enrichment Meter Principle[1]

This standard is issued under the fixed designation C1514; 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 quantitative determination of the fraction of ^{235}U in uranium using measurement of the 185.7 keV gamma-ray produced during the decay of ^{235}U.

1.2 This test method is applicable to items containing homogeneous uranium-bearing materials of known chemical composition in which the compound is considered infinitely thick with respect to 185.7 keV gamma-rays.

1.3 This test method can be used for the entire range of ^{235}U fraction as a weight percent, from depleted (0.2 % ^{235}U) to highly enriched (97.5 % ^{235}U).

1.4 Measurement of items that have not reached secular equilibrium between ^{238}U and ^{234}Th may not produce the stated bias when low-resolution detectors are used with the computational method listed in Annex A2.

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 may involve hazardous materials, operations, and equipment. 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

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

C1592 Guide for Nondestructive Assay Measurements

C26.10 Terminology Guide

2.2 *ANSI Standard:*

N42.14 Calibration and Use of Germanium Spectrometers for the Measurement of Gamma-Ray Emission Rates of Radionuclides[3]

3. Terminology

3.1 For definitions of terms used in this test method, refer to Terminology C26.10.

4. Summary of Test Method

4.1 The test method consists of measuring the emission rate of 185.7 keV gamma-rays from an item in a controlled geometry and correlating that emission rate with the enrichment of the uranium contained in the item.

4.2 Calibration is achieved using reference materials of known enrichment. Corrections are made for attenuating materials present between the uranium-bearing material and the detector and for chemical compounds different from the calibration reference materials used for calibration.

4.3 The measured items must completely fill the field of view of the detector, and must contain a uranium-bearing material which is infinitely thick with respect to the 185.7 keV gamma-ray. If the field of view is not filled, a correction factor must be applied.

5. Significance and Use

5.1 The enrichment meter principle provides a nondestructive measurement of the ^{235}U fraction of uranium-bearing items. Sampling is not required and no waste is generated, minimizing exposure to hazardous materials and resulting in reduced sampling error.

5.2 This method relies on a fixed and controlled geometry. The uranium-bearing materials in the measured items and calibration reference materials used for calibration must fill the detector field of view.

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

5.3 Use of a low resolution detector (for example, NaI detector) to measure uranium with ^{235}U fraction approximately 10 % which is contained in a thin-walled container can provide a rapid (typically 100 s), easily portable measurement system with precision of 0.6 % and bias of less than 1 %.

5.4 Use of a high resolution detector (for example, high-purity germanium) can provide measurement with a precision better than 0.2 % and a bias less than 1 % within a 300-s measurement time when measuring uranium with ^{235}U fraction in the range of 0.711 % or above which is contained in thin-walled containers.

5.5 In order to obtain optimum results using this method, the chemical composition of the item must be well known, the container wall must permit transmission of the 185.7 keV gamma-ray, and the uranium-bearing material within the item must be infinitely thick with respect to the 185.7 keV gamma-ray. All items must be in identical containers or must have a known container wall thickness and composition.

5.6 Items to be measured must be homogeneous with respect to both ^{235}U fraction and chemical composition.

5.7 When measuring items, using low-resolution detectors, in thin-walled containers that have not reached secular equilibrium (more than about 120 days after processing), either the method should not be used, additional corrections should be made to account for the age of the uranium, or high-resolution measurements should be performed.

5.8 The method is often used as a enrichment verification technique.

6. Interferences

6.1 Appropriate corrections must be made for attenuating materials present between the uranium-bearing material and the detector. Inappropriate correction for this effect can result in significant biases.

6.2 Incorrect knowledge of chemical form of the uranium-bearing materials can result in a bias.

6.3 Depending on the dead-time correction method used, excessive dead time can cause errors in live time correction and, thus, result in a measurement bias. Excessive dead time can usually be eliminated by modifications to the detector collimator and aperture.

6.4 Background gamma-rays near 185.7 keV can result in a bias. Table 1 is a list of interfering gamma-rays which may cause an interference.

TABLE 1 Interfering Gamma-Rays

Isotope	Parent	Gamma-Ray Energy (keV)	Measurement Affected
^{226}Ra	N/A	185.9	High Resolution, Low Resolution
^{212}Pb	^{232}U	238.6	Low Resolution
^{224}Ra	^{232}U	241.0	Low Resolution
^{233}Pa	^{237}Np	300.1	Low Resolution
^{233}Pa	^{237}Np	311.9	Low Resolution
^{234}Th	^{238}U	Bremsstrahlung	Low Resolution
^{99}Tc	N/A	Bremsstrahlung	Low Resolution

6.5 Any impurities present in the measured items must be homogeneously distributed and well characterized. The presence of impurities, at concentrations which can measurably attenuate the 185.7 keV gamma-ray and which are not accounted for will result in a bias.

6.6 The presence of radioactive impurities can affect the determination of the 185.7 keV peak area. This type of interference is most often encountered in low-resolution measurement, but can affect high-resolution measurements.

6.7 Other factors, such as the paint on the outside of the cylinders and the condition of the cylinder inner walls after exposure to UF_6, may affect the precision and bias for both the NaI and the HPGe measurement methods.

7. Apparatus

7.1 *Gamma-Ray Detector System*—General guidelines for selection of detectors and signal-processing electronics are discussed in Guide C1592, Test Method C1030, and ANSI standard N42.14. Refer to the References section for a list of other recommended references (**1**).[4] This system typically consists of a gamma-ray detector, spectroscopy grade amplifier, high-voltage bias supply, multi-channel analyzer, and detector collimator. The system may also include detector backshielding, an ultrasonic thickness gauge, an oscilloscope, a spectrum stabilizer, a computer, and a printer.

7.2 A high-resolution detector system or a low-resolution detector system should be selected, depending on precision and bias requirements for the measurements. Additional detector selection considerations are measurement time, cost, and ease of use. High-resolution detector systems are generally larger, heavier, and more costly than low-resolution detector systems. In addition, the cost of high-resolution detectors is significantly higher (roughly an order of magnitude) than the cost of low-resolution detectors. High-resolution systems, however, provide better results than low-resolution systems, and eliminate some interferences.

7.2.1 *High-Resolution Detector*—A high-resolution detector with a resolution of 1200 eV or better, full width at half maximum, at 122 keV is recommended. Either a planar or coaxial detector can be used, although excessive dead time can result if a coaxial detector with high (>15 %) efficiency is used. The selected detector should be of sufficient size (including a combination of surface area and thickness) to provide the desired counting-statistics based uncertainty within a reasonable counting time.

7.2.2 *Low-Resolution Detector*—A low-resolution detector with the following specifications is recommended: a 5-cm diam, 1.25-cm thick or larger detector with a resolution of 15 % or better at 122 keV.

7.2.3 *Collimator and Shield Assembly*—The detector collimator and shield assembly must be of sufficient thickness to attenuate in excess of 99.9 % of the 185.7 keV gamma-rays incident upon it. The detector collimator must also block in excess of 99.9 % of the gamma-rays incident upon it and the

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