

TABLE 7a – Uranium and Plutonium Mass by Gamma (NDA)

Method/measurement system (including software): HRGS/ISOCS

Application: ^{235}U measurement of fresh UO_2 in MTR fuel Plates or Rods

Short Description of the method/measurement system and typical measurement conditions (shielding, measurement time, etc.)
HRGS/ISOCS measurements can be performed by either liquid nitrogen cooled high resolution gamma-ray spectrometry systems (IMCG) or electrically cooled systems (ECGS) [1]. The collected high resolution gamma-ray energy spectra are analysed using computed photopeak detection efficiencies obtained from the In-Situ Object Calibration Software [2]. This allows to determine the activity (Bq) of radionuclide present in the measured item for a given item description/measurement geometry. For this application, ISOCS geometry models are based on available geometry templates describing a pre-set fixed geometry measurement. Mechanical support frames are usually used to assist inspectors in the field in reproducing the assumed measurement geometry. Description of the measured item is based on declared physical and chemical characteristics of the MTR fuel plates or rods. A measurement of ambient level of gamma-ray background radiation is performed first. This allows for the stripping the measured background spectrum from the item spectra. The ISOCS characterized measurement systems used for these measurements are typically Broad Energy (BeGe) detectors with relative efficiencies between 20 % and 50 %. Typical measurement times of 300-s for HEU items and 600-s for LEU items are used. Data acquisition is typically performed with gain setting corresponding to 0.075 keV per channel over a 16,382 channels spectrum. This allows the measurement of ^{234}U, ^{235}U and $^{238}\text{U}_{\text{eq}}$ photo-peaks up to 1,228 keV. Once a spectrum is collected, an automated spectral analysis, including peak search, peak area fitting, efficiency correction (from ISOCS), MGA-U [3] analysis and LACE steps, is performed using a predefined Analysis Sequence File (ASF). Using the specific activities of the key uranium (^{234}U, ^{235}U, $^{234\text{m}}\text{Pa}$) the activity quantification is reported in terms of mass of radionuclides. Isotopic mass ratios can also be derived (i.e. ^{235}U wt.%), although subject to the impact of potential $^{234\text{m}}\text{Pa}/^{238}\text{U}$ disequilibrium. Selection of the ISOCS efficiency calibration data is performed at the time of the execution of the ASF. Comparison of the ISOCS ^{235}U weight fractions with values derived by the MGA-U isotopic peak ratio analysis code is also performed to further evaluated the consistency of the ISOCS efficiency data/mass results, as well as visual confirmation of the consistency of the ^{235}U, $^{234\text{m}}\text{Pa}$ mass results using the Linear Activity Consistency Evaluation (LACE) plots [4].
Factors affecting the method performance
Uncertainty associated with the positioning of the measured item is limited by using mechanical holders. Measurements are usually performed in a relatively low background environment. Availability/reliability of information used in the development of the ISOCS model may impair on the measurement accuracy. This usually is the largest source of systematic error. Consistency checks between modelled and quantified results (e.g. quantified vs. modelled U masses), ISOCS based FRAM/MGA-U enrichments, and LACE provide means to gain confidence on the reliability of the ISOCS mass results. Quantification of ^{238}U via $^{234\text{m}}\text{Pa}$ peak intensities requires for the material to have reached equilibrium.

Method references
1. https://www.ortec-online.com/products/radiochemistry-health-physics-research-industrial/gamma-spectroscopy/all-in-one-spectrometers/micro-trans-spec 2. Venkataraman, R., Bronson, F., Atrashkevich, V., Young, B. M., Field, M. "Validation of in-situ object counting system (ISOCS) mathematical efficiency calibration software. Nucl. Instr. and Meth. 1999, A 422. 3. R. Gunnink, W.D. Ruhter, P. Miller, et al., "MGAU: A NEW ANALYSIS CODE FOR MEASURING ²³⁵U ENRICHMENTS IN ARBITRARY SAMPLES", UCRL-JC-114713, Livermore, 1994.
Source of bottom-up value (<u>only for prospective ITV not based on historical data</u>)
The reported ITV values originate from a very limited set of both field measurements and inspection results. These estimated performance values have been propagated to generate paired data with operator values assumed to carry only small systematic and random uncertainties as the manufactured of fuel pins usually follows very high level of quality controls/quality check analytical measurements.

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