A new approach to enrichment plant UF_6 destructive assay sample collection and analysis

N.C. Anheier[1], B.D. Cannon, A. Martinez, C. Barrett, M.S. Taubman, K. Anderson, L.E. Smith

Pacific Northwest National Laboratory
902 Battelle Boulevard
PO Box 999
Richland, WA, 99352, USA

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The International Atomic Energy Agency's (IAEA) long-term R&D plan calls for more effective and efficient safeguards methods to detect and deter misuse of gaseous centrifuge enrichment plants (GCEPs). The IAEA's current safeguards approach for GCEPs includes measurements of gross, partial, and bias defects for accountancy of the ^{235}U flow into and out of the facility and enrichment process, as well as inventory stored onsite (mostly tails in cylinders). These safeguard methods consist principally of UF_6 cylinder enrichment and mass verification using nondestructive assay (NDA) and weighing systems, respectively. A limited set of UF_6 cylinder destructive assay (DA) measurements are conducted to quantify bias defects and provide assurances that ^{235}U relative abundance values (i.e., isotope ratio $n(^{235}U)/n(^{238}U)$) are consistent with facility declarations. High-precision DA measurements also provide validation to a larger set of lower-precision NDA cylinder measurements. DA samples are collected from a sampling tap by condensing between 1–10 g of gaseous UF_6 into the sample bottle. The sample bottle is then transferred to IAEA custody. The bottle is weighed before and after sampling to determine the total sampled uranium mass. Sample bottles are packaged and tamper-sealed in an approved shipping container (e.g., 10-gallon 3919A shipping drum) and then stored onsite for up to a year. Once filled to a maximum 100 grams UF_6, the drum is then shipped under chain of custody to IAEA's Nuclear Materials Analysis Laboratory (NMAL) in Seibersdorf for high-precision assay by mass spectrometry.

Shipping and handling the DA sample drums presents many challenges. The IAEA has indicated that evolving regulations for transportation of hazardous materials are making it increasingly difficult and time-consuming to complete such shipments. The IAEA would also benefit from the ability to analyze UF_6 DA samples in the field. This approach could provide early indication of discrepancies with operator declarations during annual physical inventory verifications, so that such discrepancies could be addressed immediately, rather than after offsite analysis is completed. Advances in laboratory sample analysis methods, for DA samples that are shipped offsite, may also be desirable. Efficiency gains and timeliness improvements may be realized by more rapid and less resource-intensive analysis of DA samples at the NMAL.

[1] Corresponding author. Tel.: +001 509 375 2639. E-mail address: norm.anheier@pnnl.gov

Pacific Northwest National Laboratory (PNNL) is proposing two new safeguards technologies that may have the potential to address many of the IAEA DA safeguards challenges.[2] The first technology is the PNNL-developed Laser Ablation, Absorbance Ratio Spectrometry (LAARS) technology, which is designed to provide high-fidelity ^{235}U relative abundance measurements for either onsite or laboratory-based analysis applications. Analyzing UF_6 samples onsite by LAARS could provide early indication of discrepancies with operator declarations that could be addressed during the inspections. Routine onsite LAARS analysis could provide timely assay results and reduce the DA sample shipment inventory to just those needed for independent validation. A laboratory-based LAARS instrument could also provide rapid (<20 min/assay), cost-effective (no sample handling or chemical preparation required) sample prescreening of DA samples shipped to NMAL. Current LAARS assay measurement uncertainties are within a factor of 10 of the IAEA International Target Values (ITV) for ^{235}U DA abundance measurements and ongoing development efforts are focused on improving LAARS assay performance to reach the ITVs.

PNNL is also developing a handheld DA sampler concept to help IAEA meet impending UF_6 DA sample transportation challenges.[3] To achieve this goal, the handheld DA sampler collects and then stabilizes a much smaller uranium sample mass compared to current sampling methods (i.e., ~10 mg vs. ~10 g). The lower uranium mass significantly reduces the radioactivity of the sample, and the stabilization approach converts the sampled UF_6 gas to a non-reactive, solid uranium form (i.e., UO_2F_2). The transportation constraints should be considerably relaxed, since the shipment no longer carries the risk of airborne uranium particle and hydrogen fluoride release or the requirements associated with pressurized sample bottle shipments. The handheld DA sampler is designed as a low-cost, single-use sampling tool that collects DA samples from a conventional facility sampling tap. DA samples are quickly captured and stabilized by a small (~20 mm diameter), sorbent film-coated coupon that is contained within the handheld DA sampler. The DA coupons could be directly assayed onsite by LAARS (for example, located in a secure IAEA room) or sent to NMAL, possibly as an unregulated shipment. Once shipped, rapid and less resource-intensive analysis could be conducted using a fixed laboratory LAARS instrument or the uranium could be extracted from the coupons by microwave-assisted dissolution and then assayed by mass spectrometry. Applying the two complementary PNNL safeguards technologies offer the potential to significantly improve both the effectiveness and the efficiency of IAEA GCEP safeguards.

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[2] Anheier NC, et al. 2014. “A Laser-based Method for Onsite Analysis of UF_6 and Environmental Samples at Enrichment Plants.” Symposium on International Safeguards: Linking Strategy, Implementation and People – IAEA CN-220, Oct 2014.

[3] Barrett C.A., A. Martinez, B.K. McNamara, B.D. Cannon and N.C. Anheier. “Adsorptive Films in Support of In-Field UF_6 Destructive Assay Sample Collection and Analysis.” 2014 *55th INMM Annual Meeting Materials Control & Accountability - Destructive Analyses and Nuclear Forensics*, July 20-24.