Methods for Process Monitoring to Accurately Detect and Quantify Material Holdup in Advanced Recycle Facilities

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ABSTRACT

Scope and Objectives: International Atomic Energy Agency (IAEA) safeguards monitoring provides the primary basis for nations to have confidence that nuclear activities in other nations are peaceful. The goal of IAEA safeguards is to provide timely detection of the diversion of a significant quantity of nuclear material. This is a challenging goal for facilities that handle nuclear materials in bulk forms. Excellent design to enable reliable detection, localization, and visualization of accidental hold up ("leaks") for safety purposes has clear implications for improving IAEA safeguards also. Moreover, the fact that facility operators have strong motivation to be able to detect and visualize accidental "leaks" can be leveraged to develop new monitoring technology that can also improve the capability of IAEA safeguards. This is the primary objective of the proposed project.

Deliverables: This project will develop unique methods to *design* and *operate* reprocessing facilities and other nuclear material bulk handling facilities, including molten salt reactors (MSRs), to enable the detection of inadvertent or deliberate hold up of fissionable material with high confidence and low false-positive rates. We separate "design" from "operate," because we believe that the most important contributions from our research will involve better methods to design new facilities, as well as to operate them. Furthermore, *our application space will include aqueous reprocessing* as we anticipate our technology will be particularly useful in these facilities.

Project Description: How can one detect the diversion of very small amounts of nuclear material in a bulk-handling system that processes very large quantities? This proposal will leverage recent advances in radiation detection and imaging in combination with computer vision, advances in radiation transport methods, and strategies for non-radiation-based leak and diversion detection to develop and demonstrate unique, improved methods for achieving this goal.

We will study methods to detect small departures from expected inventories with the goal to verify that the remaining inventory of material is less than the design maximum heel (and, if feasible, to measure with precision the amount of residual material). The detection of neutrons generated by spontaneous fission is a logical priority, with coincident gamma emission enabling increased signal-to-noise. We will additionally focus on being able to make these determinations in (at least nearly) real time. Our proposal involves four primary task areas: advanced simulation, advanced detection, model-based fault detection, and facility design.

Potential Impact: These techniques and approaches for integrative advanced process monitoring will enhance nuclear Material Control and Accountability (MC&A) in used nuclear fuel reprocessing facilities and other facilities, including MSRs. We will use radiation based and non-radiation based approaches with the goal of providing quantitative analysis to supplement traditional nuclear MC&A measures resulting in improved performance of the safeguards system to meet Nuclear Regulatory Commission MC&A requirements.