
Accurate Holdup Calculations with Predictive Modeling & Data Integration

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Program: Fuel Cycle

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ABSTRACT

In facilities that process special nuclear material (SNM) it is important to account accurately for the fissile material that enters and leaves the plant. Although there are many stages and processes through which materials must be traced and measured, the focus of this project is material that is “held-up” in equipment, pipes, and ducts during normal operation and that can accumulate over time into significant quantities. Accurately estimating the holdup is essential for proper SNM accounting (*vis-à-vis* nuclear non-proliferation), criticality and radiation safety, waste management, and efficient plant operation.

Usually it is not possible to directly measure the holdup quantity and location, so these must be inferred from measured radiation fields, primarily gamma and less frequently neutrons. Current methods to quantify holdup, i.e. Generalized Geometry Holdup (GGH), primarily rely on simple source configurations and crude radiation transport models aided with *ad hoc* correction factors. This project seeks an alternate method of performing measurement-based holdup calculations using a predictive model that employs state-of-the-art radiation transport codes capable of accurately simulating such situations. Inverse and data assimilation methods will use the forward transport model to search for a source configuration that best matches the measured data and will simultaneously provide an estimate of the level of confidence in the correctness of such configuration.

In a typical holdup situation there are significantly more unknowns (e.g., the spatial distribution of radionuclides) than there are measurements of the radiation field, leading to an under-determined problem that permits multiple solutions. We will utilize a probabilistic approach, based on Bayes’ Theorem, that rates possible solutions according to their plausibility given the measurements and initial information. We dub this approach *Data Integration with Modeled Predictions* (DIMP). Newton iterations will find the best fit of the predictive model with detector measurements. At each step, the sensitivities of the detector measurements with respect to the model parameters (e.g., mass of fissile material) are computed using neutron and gamma transport simulators, and then the computed fluxes are converted to detector responses. Next, the difference between the computed and measured responses at selected detector positions drives the change in the source material distribution for the next iterative step.

DIMP’s benefits: (1) consistently integrates all available measurements, i.e. gamma and neutron fields; (2) seamlessly includes prior information about the holdup distribution based on past experience; (3) estimates the confidence level in a particular solution(s); (4) accounts for various uncertainties from detector measurements, nuclear data, or geometric uncertainties; (5) provides a best-estimate of the mass and location of held-up SNM and variance (or confidence level) of these quantities; (6) possesses modular structure so each function can be performed with optimal code.