DEVELOPMENT OF A REAL-TIME DETECTION STRATEGY FOR MATERIAL ACCOUNTANCY AND PROCESS MONITORING DURING NUCLEAR FUEL REPROCESSING USING THE UREX+3A METHOD

A Thesis

by

BRADEN GODDARD

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2009

Major Subject: Nuclear Engineering

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Approved by:

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ABSTRACT

Development of a Real-Time Detection Strategy for Material Accountancy and Process Monitoring during Nuclear Fuel Reprocessing Using the UREX+3a Method.

(December 2009)

Braden Goddard, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Sean M. McDeavitt

Reprocessing nuclear fuel is becoming more viable in the United States due to the anticipated increase in construction of nuclear power plants, the growing stockpile of existing used nuclear fuel, and a public desire to reduce the amount of this fuel. However, a new reprocessing facility in non-weapon states must be safeguarded and new reprocessing facilities in weapon states will likely have safeguards due to political and material accountancy reasons. These facilities will have state of the art controls and monitoring methods to safeguard special nuclear materials, as well as to provide real-time monitoring. The focus of this project is to enable the development of a safeguards strategy that uses well established photon measurement methods to characterize samples from the UREX+3a reprocessing method using a variety of detector types and measurement times.

It was determined that the errors from quantitative measurements were too large for traditional safeguards methods; however, a safeguards strategy based on qualitative

gamma ray and neutron measurements is proposed. The gamma ray detection equipment used in the safeguard strategy could also be used to improve the real-time process monitoring in a yet-to-be built facility. A facility that had real-time gamma detection equipment could improve product quality control and provide additional benefits, such as waste volume reduction. In addition to the spectral analyses, it was determined by Monte Carlo N Particle (MCNP) simulations that there is no noticeable self shielding for internal pipe diameters less than 2 inches, indicating that no self shielding correction factors are needed. Further, it was determined that HPGe N-type detectors would be suitable for a neutron radiation environment. Finally, the gamma ray spectra for the measured samples were simulated using MCNP and then the model was extended to predict the responses from an actual reprocessing scenario from UREX+3a applied to fuel that had a decay time of three years. The 3-year decayed fuel was more representative of commercially reprocessed fuel than the acquired UREX+3a samples.

This research found that the safeguards approach proposed in this paper would be best suited as an addition to existing safeguard strategies. Real-time gamma ray detection for process monitoring would be beneficial to a reprocessing facility and could be done with commercially available detectors.

DEDICATION

This thesis is dedicated to my mother, Petra Goddard (11/7/1954 - 11/7/2001)

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NOMENCLATURE

ANCC	Active Neutron Coincidence Counters
ANL	Argon National Laboratories
ATM	Approved Testing Material
COEX	Co-Extraction
CZT	Cadmium Zinc Telluride
FP	Fission Product
FPs	Fission Products
FPEX	Fission Product Extraction
FWHM	Full Width Half Maximum
GEB	Gaussian Energy Broadening
HPGe	High Purity Germanium
IAEA	International Atomic Energy Agency
LaBr	Latium Bromide
Ln	Lanthanides
MCA	Multi Channel Analyzer
MCNP	Monte Carlo N Particle
NaI	Sodium Iodide
NERI-C	Nuclear Energy Research Initiative for Consortia
NPEX	Neptunium Plutonium Extraction
NPT	Non-Proliferation Treaty
ORIGEN	Oak Ridge Isotope Generation and Depletion Code

ORNL	Oak Ridge National Laboratories
PNCC	Passive Neutron Coincidence Counters
PUREX	Plutonium Uranium Extraction
PWR	Pressurized Water Reactor
ROI	Region of Interest
SQ	Significant Quantity
TALSPEAK	Trivalent Actinide Lanthanide Separations by Phosphorus-Reagent Extraction from Aqueous Complexes
TBP	Tributyl Phosphate
TRU	Transuranic
TRUs	Transuranics
TRUEX	Transuranic Extraction
UREX	Uranium Extraction

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