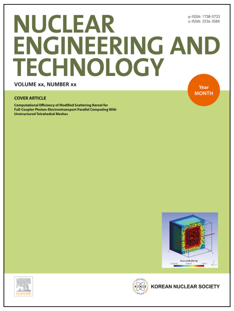

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Computational and Experimental Forensics Characterization of Weapons-grade Plutonium Produced in a Thermal Neutron Environment

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Abstract

The growing nuclear threat has amplified the need for developing diverse and accurate nuclear forensics analysis techniques to strengthen nuclear security measures. The work presented here is part of a research effort focused on developing a methodology for reactor-type discrimination of weapons-grade plutonium. In order to verify the developed methodology, natural UO_2 fuel samples were irradiated in a thermal neutron spectrum at the University of Missouri Research Reactor (MURR) and produced approximately 20 μg of weapons-grade plutonium test material. Radiation transport simulations of common thermal reactor-types that can produce weapons-grade plutonium were performed and the results are presented here. These simulations were needed to verify whether the plutonium produced in the natural UO_2 fuel samples during the experimental irradiation at MURR was a suitable representative to plutonium produced in common thermal reactor types. Also presented are comparisons of fission product and plutonium concentrations obtained from computational simulations of the experimental irradiation at MURR to the nondestructive and destructive measurements of the irradiated natural UO_2 fuel samples. Gamma spectroscopy measurements of radioactive fission products were mostly within 10%, mass spectroscopy measurements of the total plutonium mass were within 4%, and mass spectroscopy measurements of stable fission products were mostly within 5%.

Keywords – Nuclear forensics, weapons-grade plutonium, neutron irradiation

1. INTRODUCTION

Natural uranium fueled reactors are a proliferation concern due to their proficiency at producing plutonium. The mechanism for plutonium production involves a neutron capture on ^{238}U followed by two successive beta decays. The large ^{238}U concentration in natural uranium increases the production of ^{239}Pu. Subsequently, ^{239}Pu undergoes both fission and neutron capture reactions, resulting in a full suite of plutonium isotopes (^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu) also known as the plutonium vector within the irradiated fuel. It is understood that fuel exposed to a low burnup of approximately 1 GWd/MTU will result in the produced plutonium being of weapons-grade ($\geq 94\%$ ^{239}Pu) quality [1,2]. Natural uranium fuel has a lower reactivity worth than enriched uranium, leading to the need for natural uranium reactors to be refueled more frequently and at a lower burnup. Burnup being a measure of the thermal energy produced per unit mass of nuclear fuel. As a result the design of most natural uranium reactors incorporates an

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