INL/LTD-12-27592
Revision: 1
Release Date: DRAFT

Project No.: 801107

Neutron and Gamma Radiation Shielding Characteristics of X-Rok Ceramic Cements – Modeling and Validation Measurements

Douglas Akers
Keith Jewell

February 2013

The INL is a U.S. Department of Energy National Laboratory
operated by Battelle Energy Alliance.

1. SUMMARY

(Certain material identities have been redacted for proprietary reasons)

The objective of this project was to perform an initial modeling and validation measurement assessment of the radiation shielding characteristics of X-Rok ceramic cements produced by the Ceramic Cement Corporation for use on highly radioactive nuclear reactor components such as irradiated nuclear fuel assemblies. The X-Rok ceramic cement formulas evaluated had a range of compositions, densities, and neutron and gamma-ray absorption characteristics. Both neutron and gamma radiation shielding analyses were performed to assess the effects of changes in the material characteristics of the X-Rok ceramic cement composites on the neutron and gamma radiation stopping power of the X-Rok ceramic cements. Validation measurements were performed on representative samples of the cements. The measured results are considered definitive and would be expected to be used for the actual assessment of the shielding requirements for spent fuel or radioactive wastes.

The gamma-ray shielding analyses indicated that most of the X-Rok ceramic cement compositions evaluated produced improved shielding characteristics relative to the base case ([redacted]) with the exception of the boron loaded compounds, which had densities similar to or lower than the base case formulation. The [redacted] and [redacted]-loaded compounds produced similar shielding characteristics for gamma rays and had similar densities. These results indicated that the [redacted] produced better shielding characteristics than did many of the compounds and was nearer the [redacted] and [redacted], which produced the best shielding characteristics. These data suggested that slightly thicker thickness' of the basic [redacted] would function as an effective shielding material at lower cost than the more expensive [redacted] and [redacted] loaded materials.

The neutron shielding modeling results indicated large reductions in the transmitted neutron flux due to the composition of the X-Rok ceramic cement composites with a significant reduction in flux for all of the X-Rok ceramic cements. Also examination of the modeled data indicates that the primary factor in the reduction of the neutron flux from the modeled spent fuel assembly was the density of the material with the denser [redacted] producing the greatest reduction in neutron flux. However, the validation measurements performed on actual X-Rok ceramic specimens indicated that the [redacted] specimens were most effective in reducing the neutron flux of all the materials tested and would be expected to be better than [redacted] [redacted] as the effective neutron cross section for [redacted] was better than that for the [redacted] [redacted], which was not measured. Consequently, it is expected that layered or sequential X-Rok ceramic cements with layers of [redacted] cement layers and layers of more effective cements such as the [redacted] will be effective for both gamma and neutron shielding.

The gamma and neutron shielding analyses and measurements were performed as an assessment of the characteristics of the X-Rok ceramic cement composites and to provide a basis for developing shielding designs for spent fuel or radioactive wastes. The validation measurements demonstrate the effectiveness of the X-Rok ceramic cement composites for both gamma-ray and neutron shielding.