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By

Rene Sanchez, David Loaiza, and John Bennion

Introduction

A series of experiments have been performed containing highly enriched uranium, hydrogenous moderator (polyethylene), and gadolinium as a neutron absorber. The purpose of the experiments is to provide additional criticality data that can be used to verify and validate criticality safety evaluations in support of the National Spent Fuel Program. In addition, the experiments were also designed to provide criticality data for heterogeneous systems as noted in reference 1.

Description of the Experiments

The critical mass experiments were fueled with highly enriched uranium foils. The average dimensions of the bare foils were 22.86-cm square and 0.00762-cm thick. The foils were laminated with plastic sheets to reduce the amount of airborne contamination. Each foil weighed approximately 70-g and the isotopic composition was 93.23 w% ^{235}U, 5.37 w% ^{238}U, 0.26 w% ^{236}U, and 1.13 w% ^{234}U. The gadolinium foils were 5.08-cm square and 0.038-cm thick. Each gadolinium foil weighed approximately 8-g and was 99.68 w% gadolinium metal. The gadolinium foils were placed in the center of the uranium foils. Two types of experiments were performed on the Planet[2] vertical assembly machine.

The unit cell for the first experiment was defined as 22.86-cm by 22.86-cm. Each unit cell contained two uranium foils. Only the top uranium foil of each cell had a gadolinium foil in the central position. The fuel was interleaved between plates of high-density polyethylene. The polyethylene plates were 39.12-cm square and 1.91-cm thick. There were eight 39.12-cm square and 2.54-cm thick high-density polyethylene plates that form the top and bottom reflector (four at the top and four at the bottom).

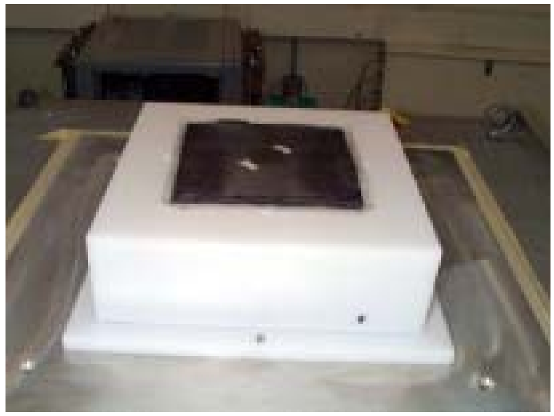
The unit cell for the second experiment was defined as 45.7-cm by 45.7-cm and contained four uranium foils whose dimensions were stated above. Each of the four uranium foils had a gadolinium foil in the central position. Again, the fuel was interleaved between high-density polyethylene plates. The bottom part of the core had polyethylene plates whose dimension were 66.04-cm square and approximately 1-cm thick. The dimensions of the polyethylene plates on the top part of the core were 75.2-cm square and 1-cm thick. There were eight 66.04-cm square and 2.54-cm thick plates that form the top and bottom reflector (four at the top and four at the bottom). Figure 1 shows the two configurations that were studied. Note that the gadolinium foils are placed on the top of each uranium foil.

Results

1/M curves were plotted based upon the normalized counting rates as a function of number of unit cells and as a function of separation distance. Table I summarizes the critical configurations. It is important to note that even though the hydrogen content in the second experiment is a bit greater than the first one, the critical mass increases because the amount of gadolinium is greater in the second experiment as seen in table I. In addition, the reactivity worth of the gadolinium in the second experiment is worth more than the first one because in the second experiment there is more hydrogen and the absorption cross-section for gadolinium is larger for this system due to the 1/v behavior. The spectral characteristics of these experiments were compared with benchmark experiments that have been documented in the International Handbook of Evaluated Criticality Safety Benchmark Experiments (IHECSBE).[1, 3] It was found that the existing benchmark experiments bound quite well the experiments that are being presented in this summary. Future experiments will be performed with thinner gadolinium foils. It is expected that the critical masses for these systems will remain unchanged because the thinner gadolinium foils may be already black to neutrons. Therefore, their reactivity worth will be same as the thicker ones.

Table I. Critical parameters of Uranium diluted with Gd and polyethylene systems.

Final measured configuration		Critical configuration		
$H/^{235}U$, $Gd/^{235}U$	Mass of Uranium (g)	Extrapolated critical mass g of U	Core average density (g/cc) Uranium	Core average density (g/cc) diluent
$H/^{235}U = 230$, $Gd/^{235}U = 0.09$	1951.3	1958.3	0.146	For Gd density = 0.008 For CH_2 density = 0.961
$H/^{235}U = 245$, $Gd/^{235}U = 0.18$	2801.0	2872.8	0.141	For Gd density = 0.016 For CH_2 density = 0.961



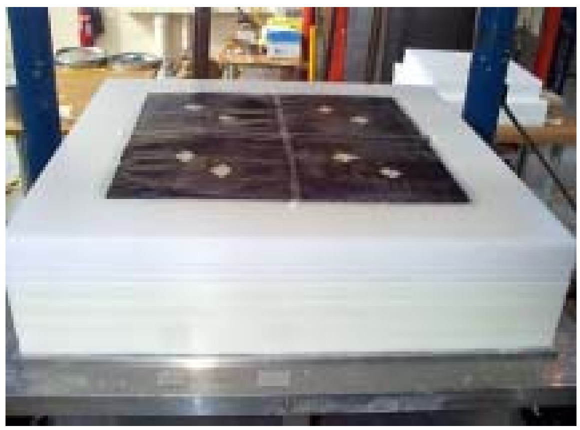


Figure 1. Configurations with Gd foils that were studied.

References

1. J. S. Bennion, and J. W. Nilesen, “Design of Nuclear Criticality Safety Experiments for HEU/H/Gd Systems,” Idaho State University report TR99/00-003, (2000).
2. R. R. Paternoster, et al., “Safety Analysis Report for the Los Alamos Critical Experiments Facility (LACEF) and the Hillside Vault (PL-26),” Los Alamos National laboratory report LA-CP-92-235, (1998).
3. International Handbook of Evaluated Criticality Safety Benchmark Experiments, NEA/NSC/DOC (95) 03, Nuclear Energy Agency, Organization for Economic Cooperation and Development, September 1999 edition.