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Title: Prompt Neutron Decay Constants in Uranium Diluted with Matrix Material Systems

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Prompt Neutron Decay Constants in Uranium Diluted with Matrix Material Systems

By

Rene Sanchez, David Loaiza, and Glen Brunson

Introduction

Rossi-Alpha measurements were performed on uranium diluted with matrix material systems to determine the prompt neutron decay constants. These constants represent an eigenvalue characteristic of these particular critical assemblies, which can be experimentally measured by the Rossi-Alpha or pulse neutron source techniques and calculated by a deterministic or Monte Carlo method. In the measurements presented in this summary, highly enriched foils diluted in various $X/^{235}U$ ratios with polyethylene and SiO_2, and polyethylene and aluminum were assembled to a high multiplication and the prompt neutron decay constants were obtained by the Rossi-Alpha technique.[1]

Description of the Experiments

The uranium diluted with matrix material experiments were fueled with highly enriched uranium foils.[2] The average dimensions of the bare foils were 22.86-cm squared 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. The diluent material consisted of SiO_2, or 6061 aluminum plates, which were embedded into polyethylene plates. The SiO_2 and aluminum plates were 22.86-cm squared and 0.64-cm thick. The polyethylene plates were 39.12-cm squared and 1.91-cm thick. Each polyethylene plate had a central recess whose dimensions were 22.86-cm by 22.86-cm by 0.64-cm deep and was used to accommodate the SiO_2, or aluminum plates as well as the uranium foils.

There were eight 39.12-cm squared by 2.54-cm thick high-density polyethylene plates that form the top and bottom reflector (four at the top and four at the bottom). Also one of the polyethylene plates located in the center of the assembly had holes drilled in a radial direction to accommodate neutron detectors. Four ^{3}He detectors were placed in this plate. The ^{3}He detectors were 1.27-cm in diameter and approximately 15-cm long. Rossi-Alpha measurements were performed at several subcritical separations for both experiments. The data were collected with a type I time analyzer (PATRM).[3,4] This time analyzer has the capability of time tagging each arrival pulse from each of the neutron detectors and sort them one by one into a time window containing 100 bins. The stored data can be analyzed using different time windows without having to retake the data. The alphas for both experiments at different subcritical separations were obtained from least square fits to the functional forms $f(t) = A\exp(-\alpha t) + C$ and $f(t) = A\exp(-\alpha_1 t) + B\exp(-\alpha_2 t) + C$. The prompt neutron decay constants at delayed critical were obtained by plotting the alphas at a particular subcritical separation as a function of the inverse count rate and extrapolating linearly to an inverse count rate of zero (delayed critical).

Results

Table I shows the delayed critical prompt neutron decay constants for the uranium/SiO_2/polyethylene, and uranium/aluminum/polyethylene experiments. It is important to note that for both experiments the least square fit to one exponential was not the perfect fit because the system was operated at a high multiplication (high count rates) and the detection system experienced some saturation. However, when we removed the neutron source and counted for longer periods of time at these high multiplications, the fit approached a one exponential function. In addition, for the two exponential function, the ratio of the amplitude, A, of the fundamental mode exponential to the second exponential amplitude, B, tends to increase as any of the systems approaches delayed critical. Thus, the second exponential dies away leaving the fundamental mode exponential and decay constant, which is very similar to the one exponential fit decay constant (see table I). Based on the fact that both alphas are statistically the same, we can say that the neutron lifetime for both systems is approximately the same. Finally, the temperature of the experiments was kept within 1 °C for each run, which would yield essentially the same alpha if we consider that the temperature coefficient for these experiments is on the order of $0.03/°C.

Table I Prompt neutron decay constants at delayed critical for uranium diluted with matrix material systems.

<table>
<tr><td>Uranium/SiO_2/polyethylene. Si/^{235}U = 21, H/^{235}U = 156. Detector location and source location.</td><td colspan="2">α(1/sec)</td><td>Temperature (°C)</td></tr>
<tr><td rowspan="3">Detectors were placed in the center of the assembly approximately 18.4-cm from the top reflector. Neutron source was placed in the movable platen.</td><td colspan="2">223.1 ± 4.0</td><td rowspan="3">25.5</td></tr>
<tr><td>α_1(1/sec)</td><td>α_2(1/sec)</td></tr>
<tr><td>218.3 ± 2.0</td><td>13500 ± 3500</td></tr>
<tr><td>Uranium/Al/polyethylene. Al/^{235}U = 60, H/^{235}U = 159. Detector location and source location.</td><td colspan="2">α(1/sec)</td><td>Temperature (°C)</td></tr>
<tr><td rowspan="3">Detectors were placed in the center of the assembly approximately 20.3-cm from the top reflector. Neutron source was placed fro some runs in the movable part of the core and for others in the stationary part of the core.</td><td colspan="2">212.8 ± 9.0</td><td rowspan="3">25.6</td></tr>
<tr><td>α_1(1/sec)</td><td>α_2(1/sec)</td></tr>
<tr><td>209 ± 9.0</td><td>-</td></tr>
</table>

References

1. J. Orndoff, “Prompt Neutron Periods of Metal Critical Assemblies,” Nucl. Sci. Eng., 2, 450 (1957).
2. R. Sanchez, et al., “Critical Masses of Uranium Diluted with Matrix Material,” Los Alamos National laboratory report LA-UR-99-4952, (1999).
3. G. S. Brunson and G. J. Arnone, “Applications of a Versatile New Instrument Module,” Los Alamos National Laboratory report LA-13271-MS, (1997).

4. G. J. Arnone, et al., "A Pulse Arrival-Time Recording Module (PATRM) for Analyzing Neutron Multiplicities," Los Alamos National Laboratory report LA-UR-92-3460, (1992).