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Author(s):

C. L. Hollas, C. A. Goulding, and W. L. Myers

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Non Destructive Analysis of Shielded Highly Enriched Uranium

C. L. Hollas, C. A. Goulding, and W. L. Myers
Los Alamos National Laboratory
Los Alamos, New Mexico, USA

Arms control and special nuclear material reduction requirements will eventually encompass shielded highly enriched uranium (HEU) systems. Non-destructive analysis (NDA) techniques for plutonium such as neutron multiplicity measurements and analysis are well developed and provide information regarding the properties of plutonium systems. In a previous study[1] we developed a NDA method for determining the mass and neutron multiplication of subcritical bare metal systems of HEU. In this work we present results for a HEU sphere enclosed within various shielding materials of low density, (carbon and beryllium), medium density (iron) and high density (lead).

The method uses delayed neutrons from fission products as a source of interrogating neutrons. The fission products are from fission events produced by an external radiation probe of pulsed 14-MeV neutrons. Neutrons are detected between pulses of the interrogating probe by a medium efficiency ^{3}He based neutron detector system. The neutron detection times are recorded, and subsequently analyzed with the Feynman reduced variance method [2,3]. This analysis provides a measure of the number of "single" (N1), "double" (N2), and "triple" (N3) neutron events detected from fission events. Ratios of doubles/singles and triples/singles are compared to calculations based on the Hage-Cifarelli[4] model to determine values for the multiplication of the HEU sample.

The uranium sample enriched to 93.12% ^{235}U of average density 18.675g/cm^3 , was a solid sphere of radius 4.0 cm and mass 4.79 kg.

The N1/sec, N2/sec and N3/sec distributions for the bare 4.79 kg HEU sphere are shown on a log scale in Fig. 1. The data for the "singles" measurement N1/sec is shown as diamonds, the "doubles", N2/sec, distribution as triangles and the "triples", N3/sec, distribution as squares. No data is recorded during the 14-MeV neutron beam burst and for the following ~1000 usec. Each time interval is the result of an independent Feynman histogram. The data between 6000 usec to 16000 usec is averaged to obtain experimental results for N1/sec, N2/sec and N3/sec. The variation of the values about the mean determines the statistical precision.

For the shielding materials examined in this study, only small changes are observed for the N1/sec, N2/sec and N3/sec values. In general an increase in N2/N1 and N3/N1 ratios

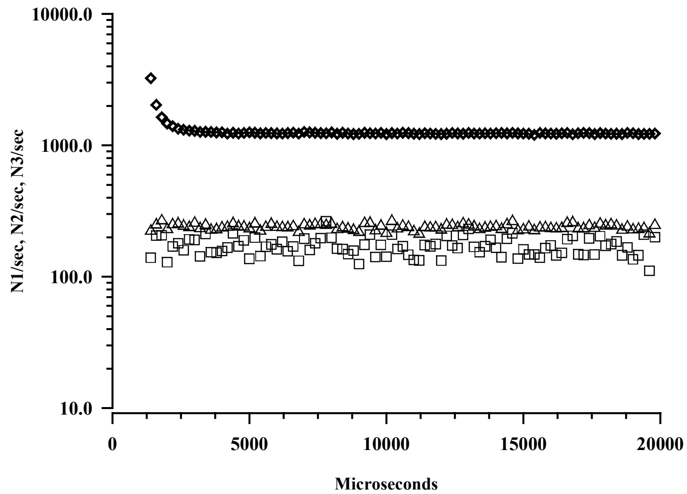

FIG. 1. The time dependence of N1/sec(diamonds), N2/sec (triangles) and N3/sec (squares) after the 14-MeV neutron beam bursts for the bare configuration containing 4.79 kilo-grams of HEU.

are observed, which corresponds to an increase in the neutron multiplication due to neutrons which are reflected back onto the HEU sample. The multiplication values as well as those calculated with the Onedant computer code are listed in Table 1. The experimentally determined mass values are also listed in the table.

Table 1 . Values for the experimental and calculated neutron multiplication and HEU mass.

Material	**Thickness cm**	**Multiplication Total Experiment**	**Multiplication Total Onedant**	**Ratio Exp/Calc**	**Mass Experimental**
None	**0.00**	**1.89**	**1.85**	**1.02**	**4.79**
Beryllium	**1.59**	**2.17**	**2.44**	**0.89**	**4.33**
Carbon	**2.54**	**1.84**	**1.89**	**0.97**	**5.08**
Iron	**3.18**	**1.97**	**1.92**	**1.03**	**4.67**
Iron	**1.27**	**1.92**	**1.89**	**1.02**	**4.71**
Lead	**4.45**	**2.01**	**1.92**	**1.04**	**4.60**
Lead	**1.27**	**1.92**	**1.89**	**1.02**	**4.71**

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[3] ROBBA, A. A. et. al. “Neutron Multiplication Measurements Using Moments of the Neutron Counting Distribution”, Nucl. Instr. and Meth. **215**, (1983) 473-479.
[4] CIFARELLI, D. M. and HAGE, W. “Three Parameter Analysis of Neutron Signal Correlation Measurements”, Nucl. Instr. and Meth. **A251**, (1986) 550-563.