LA-UR-04-0216

Approved for public release; distribution is unlimited.

Title: Criticality of a Neptunium-237 Surrounded withHighly Enriched Uranium Shells and an Iron Reflector

Author(s): Rene Sanchez, David Loaiza, David Hayes, and Robert Kimpland

Submitted to: ANS Annual Meeting to be held in Pittsburgh, PA June 13-17, 2004

LOS ALAMOS NATIONAL LABORATORY

3 9338 00995 2655

Los Alamos

NATIONAL LABORATORY

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the U.S. Department of Energy under contract W-7405-ENG-36. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

Form 836 (8/00)

Criticality of a Neptunium-237 Sphere Surrounded with

Highly Enriched Uranium Shells and an Iron Reflector

Rene Sanchez, David Loaiza, David Hayes, and Robert Kimpland

Los Alamos National Laboratory: P. O. Box 1663, Los Alamos, NM, 87545, rsanchez@lanl.gov

INTRODUCTION

An additional experiment has been performed using the recently cast 6-kg ^{237}Np sphere. The experiment consisted of surrounding the neptunium sphere with highly enriched uranium and an iron reflector. The purpose of the critical experiment is to provide additional criticality data that can be used to validate criticality safety evaluations involving the deposition of neptunium.

It is well known that ^{237}Np is primarily produced by successive neutron capture events in ^{235}U or through the (n, 2n) reaction in ^{238}U. These nuclear reactions (see Eq. 1) lead to the production of ^{237}U, which decays by beta emission into ^{237}Np. In addition, in the spent fuel, ^{241}Am decays by alpha emission into ^{237}Np.

$$^{235}U\ (n, \gamma)\ ^{236}U$$

$$^{236}U\ (n, \gamma)\ ^{237}U \rightarrow \beta \rightarrow\ ^{237}Np \qquad (1)$$

$$^{238}U\ (n, 2n)\ ^{237}U \rightarrow \beta \rightarrow\ ^{237}Np$$

$$^{241}Am \rightarrow \alpha \rightarrow\ ^{237}Np$$

Because ^{237}Np is a threshold fissioner, the best reflectors for critical systems containing neptunium are those materials that exhibit good neutron scattering properties such as low carbon steel (99 wt % Fe). In this experiment, the iron reflector reduced the amount of uranium used in the critical experiment and increased the importance of the neptunium sphere.

DESCRIPTION OF THE ACTUAL WORK

The experiment was performed on the Planet[1] vertical assembly machine at Los Alamos National Laboratory. The critical mass experiment consisted of surrounding the 6-kg ^{237}Np sphere with highly enriched uranium (HEU) nesting shells and an iron reflector until criticality was achieved. The neptunium sphere was 8.29-cm in diameter and its calculated density was 20.29 g/cc. The sphere weighed 6070.4 g and the chemical analysis showed that the sphere was 98.8 wt % neptunium, 0.035 wt % uranium, and 0.0355 wt % plutonium.

To reduce the radiation exposure to workers, the neptunium sphere was clad with a 0.261-cm-thick layer of tungsten, and two 0.191-cm-thick layers of nickel. The gamma radiation exposure at contact was 300 mR/h. The total weight of the sphere, including the clad materials, was 8026.9 g.

The dimensions of the iron reflectors were as follows. The top reflector had a 43.18-cm outer diameter and 16.69-cm inner diameter. It weighed approximately 154 kg. The bottom reflector had a 40.13-cm outer diameter and the same inner diameter as the top reflector. This reflector weighed 122 kg.

The starting configuration is shown in Fig. 1 and consisted of the neptunium sphere and several HEU shells surrounding the neptunium sphere. An aluminum spacer was used to perfectly accommodate the neptunium sphere in the first set of HEU shells. The HEU nesting shells vary in weight from approximately 1–34 kg. Four BF_3 neutron detectors were used to monitor the neutron population.

A 1/M approach as a function of separation was performed remotely to ensure that the neptunium sphere and the oralloy shells surrounding the neptunium sphere could be safely loaded into one of the large iron reflectors (see Fig. 1). Once it was determined that the loading task was safe, the neptunium sphere and up to 34,323.3 g of HEU shells were loaded in the bottom reflector that was placed on the movable platen of the Planet assembly (see Fig. 2). The bottom reflector containing the core was aligned with a thin aluminum plate that had the same inner and outer dimension as the top iron reflector. The thin aluminum plate was suspended on the top platform of the Planet assembly and the movable platen was then raised to make sure that core containing the neptunium sphere was perfectly aligned with the hole in the thin aluminum plate. Once the alignment operation was completed, the Planet assembly was scrammed and the top iron reflector was placed on the top platform as shown in Fig. 2. The bottom part of the core was then raised and a 1/M as a function of separation was performed to determine the critical separation.

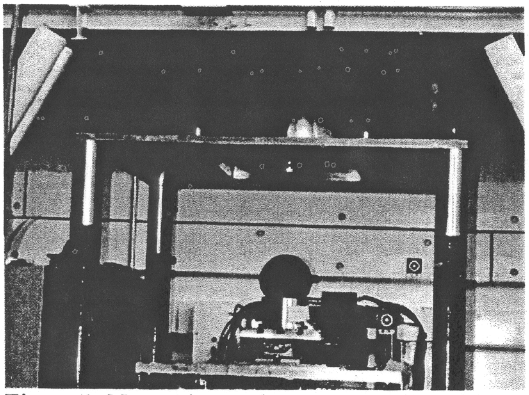

Figure 1. Neptunium sphere surrounded with HEU shells safely loaded into the large iron reflector.

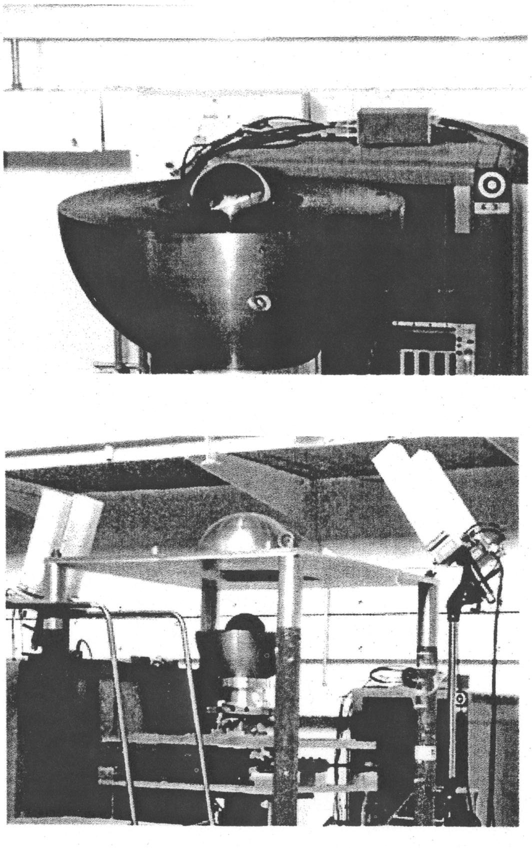

Fig. 2. Loading of the neptunium sphere in the bottom reflector and final configuration of the ^{237}Np/HEU iron reflected experiment.

RESULTS

A 1/M curve was plotted based upon the normalized counting rates as a function of separation distance. The total uranium mass in the system was 34,323.3 g. Criticality was attained at a separation of approximately 0.460 inches. Figure 3 shows the excess reactivity based on two reactor periods that were taken above delayed critical. This figure indicates that at closure, which occurs at 0.054 inches, the excess reactivity in the system is 3.61$. An aluminum spacer will be placed between the two halves to limit the excess reactivity to less than 0.50$.

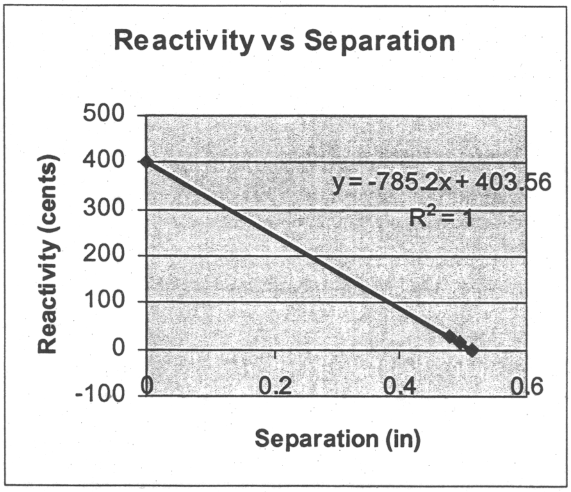

Figure 3.

REFERENCES

1. 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 (1992).