

The results obtained in these first two series of experiments are summarized in Table I along with a description of each assembly.

In a third series of experiments, measurements were performed to determine the effect of boron loading (creating a neutron flux trap) on the effective neutron multiplication constant ( $k_{eff}$ ). In this series of experiments, pulse neutron source measurements were performed to determine the  $k_{eff}$  of neutron flux trap assemblies having multiple fuel loadings for each of the four boron concentrations of 0.45, 0.36, 0.13, and 0.05 g B/cm<sup>2</sup>. In each experimental assembly, the fuel rods were equally distributed among four units. Each fuel unit was located  $0.295 \pm 0.40$  cm from the borated plates. Measurements were performed at three assembly fuel loadings (306, 676, and 855 fuel rods) as a function of boron loading in the plates creating the neutron flux trap. The results obtained from this third series of measurements are summarized in Table II.

1. S. R. BIERMAN, "Criticality Experiments to Provide Benchmark Data on Neutron Flux Traps," PNL-6205, Pacific Northwest Lab (1987).
2. S. R. BIERMAN, E. D. CLAYTON, "Criticality Experiments with Subcritical Clusters of 2.35 wt% and 4.35 wt% <sup>235</sup>U Enriched UO<sub>2</sub> Rods in Water and a Water-to-Fuel Volume Ratio of 1.6," PNL-3314, Pacific Northwest Lab. (1980).
3. E. GARELIS, J. L. RUSSELL, "Theory of Pulsed Neutron Source Measurements," *Nucl. Sci. Eng.*, 16, 263 (1963).
4. T. GOZANI, P. DeMARMELS, T. HURLIMAN, H. WINKLER, "On the Modified Pulse Source Techniques," *Proc. Symp. Pulsed Neutron Research*, Karlsruhe, FRG, Vol II, p. 49, International Atomic Energy Agency, Vienna (1965).

### 3. Criticality Experiments with Mixed Plutonium-Uranium Nitrate Solution at Plutonium Fractions of 0.2, 0.5, and 1.0 in Annular Cylindrical Geometry, R. C. Lloyd (PNL), T. Koyama (PNC R&D-Japan)

The objective of these criticality experiments is to provide criticality data for Pu + U solutions for optimizing the physical size of equipment during fissile product conversion and storage and for the design of reprocessing plants. Prior to these measurements, little or no criticality data were available for mixed plutonium-uranium solutions in annular geometry. The experiments were performed under a joint Criticality Data Development Program between the U.S. Department of Energy and the Power Reactor and Nuclear Fuel Development Corporation of Japan. The critical experiments were performed in the critical mass facility of Pacific Northwest Laboratory.

Criticality measurements were made with (Pu + U) nitrate solutions in a water-reflected annular vessel (see Fig. 1). The concentration of (Pu + U) in the nitrate solution was varied and ranged between 61 and 489 g (Pu + U)/l. The ratio of Pu to (Pu + U) in the solution also was varied, with measurements being made at ~0.52, ~0.23, and ~0.97.

The annular cylindrical vessel shown in Fig. 1 was fabricated of Type 304L stainless steel. This vessel had a 53.3-cm o.d. and a 25.4-cm i.d. The height of the fuel region was

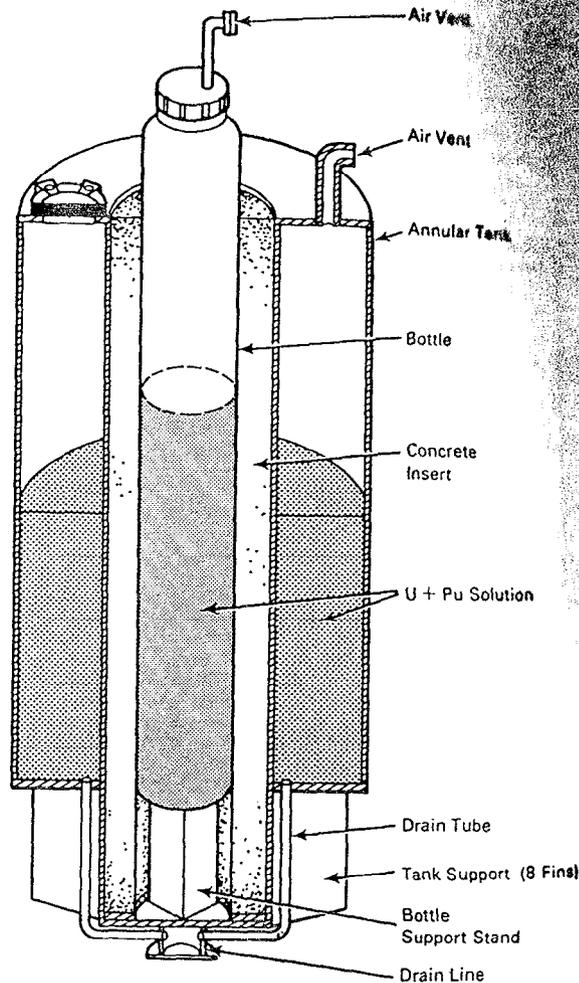


Fig. 1. Schematic of the annular cylindrical vessel with concrete insert and bottle.

105.7 cm. The wall thickness was 0.079 cm. The control and safety blades (not shown) were external to the vessel and were fully withdrawn while making the neutron flux determination during the critical approach measurement. The fill, dump, and manometer lines entered the bottom of the vessel through the dump valve system. The vessel was connected to the dump valve pedestal by a Marmon flange connection, providing a leaktight seal.

The experiments with the annular cylinder were conducted with the reflector tank containing water. The reflector tank was filled to a level below the top of the cylindrical vessel as indicated in Table I, which includes experimental data from the measurements made on the annular cylindrical vessel with various inserts placed in the central region. Six different inserts were made up by using borated concrete with different B<sub>4</sub>C content and from polyethylene with cadmium sheet on the bottom and lateral surfaces. Bottles of (Pu + U) nitrate solution were also placed inside the borated concrete or plastic inserts or positioned separately in the central void region of the annular vessel. In two of the experiments, the central region of the annular tank was completely filled with a solid polyethylene insert having a layer of cadmium sheet on the outer lateral face of the plastic (see Table I for specific cases and further description).

The cadmium-covered solid polyethylene insert (part 28) placed in the central region was very effective in reducing the neutron interaction and thereby increased the critical height. (Note results for experiments 088 and 100 as listed in Table I.) Also, it is apparent that the combination of the concrete insert (no  $B_4C$ ) and solution bottle as used in experiment 091 was more reactive (critical solution height in annular vessel smaller) than when the concrete insert was removed, and the central region contained only the bottle of (Pu + U) nitrate solution with an air gap in lieu of the concrete as in experiment 094.

The measurements provide data essential for validating criticality codes that may be used on configurations similar to those of the experiments.

#### **4. Validation Studies Performed with Mixed Pu + U Aqueous Critical Experiments in Annular Geometry, Gary R. Smolen (ORNL), H. Yamana (PNC-Japan)**

This paper discusses the results of a calculational study that was performed to validate the SCALE computer code system using data from critical experiments performed with mixed Pu + U aqueous solutions. The critical experiments were conducted in an annular vessel where the fissile solution

was placed in the annulus, and various inserts and bottles containing fissile solution were located in the inner portion of the vessel. These experimental activities are part of a joint exchange program between the U.S. Department of Energy and the Power Reactor and Nuclear Fuel Development Corporation of Japan in the area of criticality data development.<sup>1</sup> The experiments were conducted at the Battelle Pacific Northwest Laboratory's Critical Mass Laboratory (CML).

Annular tanks are used throughout the world to store fissile solutions in a manner that is floor space efficient while utilizing favorable geometry for criticality control.<sup>2</sup> In order to take full advantage of this annular geometry, critical experiments are needed to conduct computer code validation studies. In the past, critical experiments have been performed with annular vessels using fully enriched uranium<sup>3</sup> and plutonium solutions.<sup>4</sup> A companion paper reports on critical experiments that were conducted as part of the joint exchange program with mixed uranium and plutonium solutions.<sup>5</sup>

Effective multiplication factors have been calculated for 18 critical experiments. As a continuation of the effort to validate a particular computer code system and cross-section library, the calculations were performed with the SCALE code system<sup>6</sup> and the 27-energy-group Criticality Safety Reference Library<sup>7</sup> (CSRL). The CSRL was derived from Evaluated Nuclear Data File B—Version IV (ENDF/B-IV). The computer code NITAWL was used to perform the Nordheim integral treatment for the resolved resonance region, and