Consolidated Fuel Reprocessing Program

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CRITICALITY EXPERIMENTS WITH A MIXED OXIDE FUEL PIN ARRAY IN PLUTONIUM-URANIUM NITRATE SOLUTIONS*

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A series of critical experiments was completed with an array of mixed oxide fuel pins surrounded by plutonium-uranium nitrate solutions. The experiments were performed under a joint Criticality Data Development Program between the United States Department of Energy, and the Power Reactor and Nuclear fuel Development Corporation of Japan[1]. The critical experiments were performed in the Critical Mass Laboratory (CML) of the Pacific Northwest Laboratory.

The objectives of these experiments are to provide criticality data for a heterogeneous system of fuel pins moderated with plutonium-uranium solutions, and to determine the effectiveness of soluble gadolinium as a neutron absorber for criticality control in optimizing the physical size of equipment. Experiments have been performed in a similar configuration[2], however these new experiments provide criticality data for a tighter fuel lump spacing, where soluble neutron poisons are not as effective.

A boiler tube-type tank was fabricated of 304L stainless steel including a fixed array of guide tubes, as noted in the schematic of the vessel shown in Figure 1. The outside diameter of the vessel was 53.2 cm. The wall thickness of the vessel was 0.091 cm. This particular design was required in order to isolate (prevent contamination of) the fuel pins from the plutonium-bearing solutions. The design of the vessel incorporated a means of attaching the guide tubes to the top plate in a manner that did not warp the plate. The top end of the tube was flared and mechanically sealed with a screw-type compression fitting. The tubes were sealed on the bottom by 0.635-cm long plugs laser welded into the ends of the tubes. Only the mechanically sealed end of the tubes were attached to the top plate to prevent bowing of the tubes as a result of differential thermal expansion.

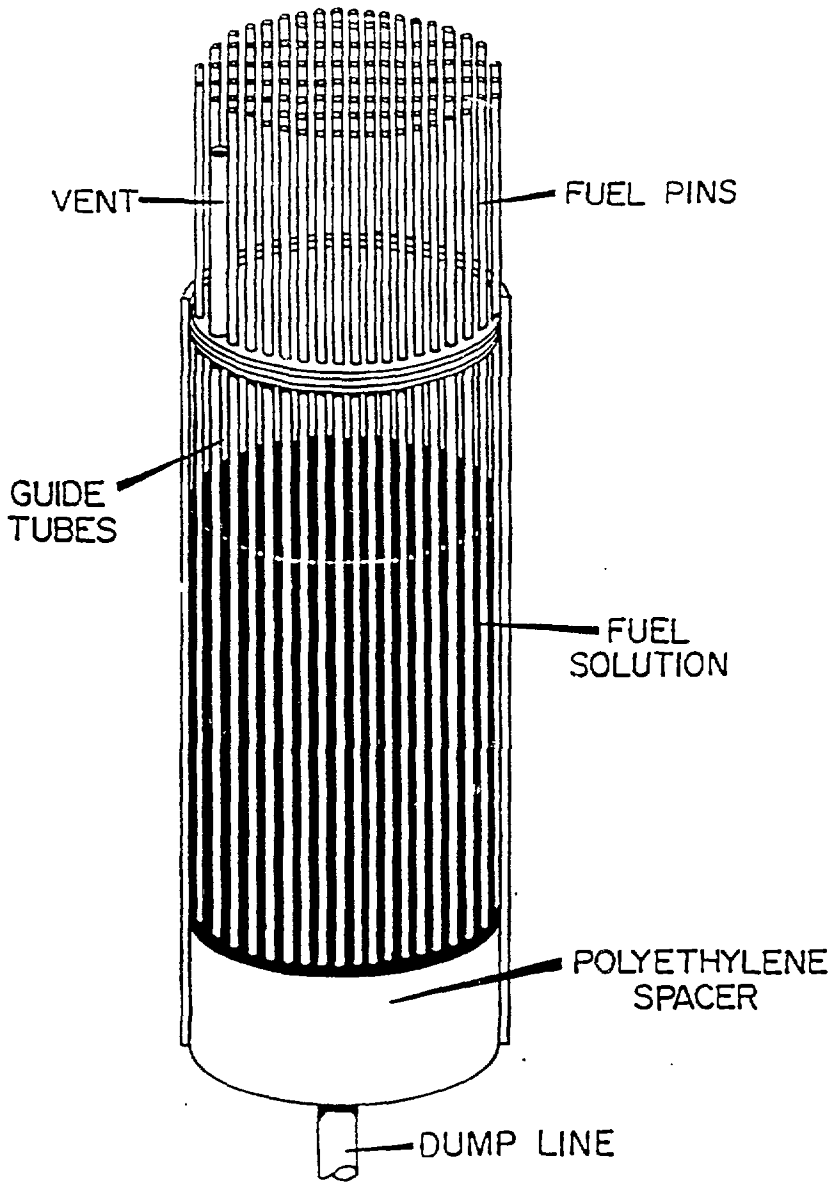

FIGURE 1. Schematic of Boiler Tube-Type Tank

During critical experiments, 996 Type 3.2 Fast Flux Test Facility (FFTF) fuel pins were placed inside the tubes, and the tubes were surrounded by various solutions. These fuel pins were also used in other critical experiments that were performed at the PNL-CML[3, 4]. The fuel pins were referred to as Fast Test Reactor pins in those reports. The Type 3.2 FFTF fuel pins contain 19.78 wt% plutonium with a 91.4 cm long mixed oxide (MOX) fuel region. The remainder of the pin consists of uranium and Inconel reflectors, end caps and other hardware.

A polyethylene spacer was placed at the bottom of the vessel, in the region below the MOX fuel, to effectively exclude fissile solution from this region. The vessel was designed so that the bottom of MOX fuel would be at the same elevation as the upper surface of the polyethylene spacer. Therefore, neutron multiplication occurs only in the region of interest (i.e., where the MOX is surrounded by fissile solution). The square lattice spacing for the fuel pins was 1.40 cm, center-to-center.

The control and safety blades were external to the vessel and were withdrawn during the neutron flux measurements taken in the course of the critical approach. The experiments with the boiler tube-type tank were conducted with the reflector tank containing water. The reflector tank was filled to a level 13 cm above the top of the MOX fuel region. The distance between the boiler tube-type tank bottom (outside surface) and the bottom of the reflector tank is 16.0.

The criticality data are summarized in Table I where the critical heights are given for the plutonium nitrate solution in the boiler tube-type tank assembly loaded with the 996 MOX fuel pins. The plutonium nitrate solution had a Pu to (Pu + U) ratio of about 0.2. Criticality measurements were made at concentrations varying from 4 to 468 g (Pu + U)/liter. Measurements were also made with solution containing about 464 g (Pu + U)/liter and varying the Gd content from 0 to 2.16 g/liter. The experiments show that the heavy metal in solution acts as a poison, since for the 1.4 cm lattice pitch, the system is undermoderated. The data may be used to validate computer codes for use in criticality calculations on these type systems.

TABLE I. Criticality Measurements with Plutonium-Uranium Nitrate Solution in the Boiler Tube-Type Tank[(a)]

Run Date	CML Experiment Number	Pu (g/liter)	U (g/liter)	Gd (g/liter)	Critical[(b)] Solution Height (cm)
11/04/87	106	0.88	2.7	0.0	18.41
11/05/87	106R	0.88	2.7	0.0	18.55
11/09/87	107	73.95	254.09	0.0	21.34
11/19/87	109	47.50	163.06	0.0	20.01
11/24/87	110	22.63	77.84	0.0	18.90
11/25/87	110R	22.63	77.84	0.0	19.03
12/02/87	111	103.70	363.98	0.0	23.87
12/09/87	112	103.18	360.62	0.49	30.28
12/11/87	113	102.23	359.69	0.98	38.78
12/17/87	114	102.65	359.59	1.47	51.06
12/23/87	115	102.68	359.55	1.97	73.08
12/31/87	116	103.61	362.45	2.16	90.27
04/04/88	117	83.30	286.57	0.0	27.42

(a) Boiler tube-type tank contained 996 FFTF Type 3.2 pins except for experiment 117 where the fuel pins were removed. The vessel was water reflected.

(b) Zero reference is the top of the polyethylene spacer.

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