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PHYSICS VERIFICATION PROGRAM
PART III, TASK 11
- QUARTERLY TECHNICAL REPORT -
April-June 1974

by
M. N. Baldwin

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ABSTRACT

In experimental Task 11, the reactivity and power perturbation effects of poison pins in mockups of 17 by 17 fuel assemblies are being measured. The experimental facility - a water-moderated, slightly enriched UO_2 lattice - is arranged to mock up the fuel assemblies of a commercial pressurized water reactor. Each assembly contains 24 poison pin positions.

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1. INTRODUCTION

In January 1974, Babcock & Wilcox (B&W) began Part III, Task 11, of the Physics Verification Program, entitled "17 by 17 Subassembly Mockups." The program is jointly sponsored by B&W and the U.S. Atomic Energy Commission. A principal objective of the task is to measure the reactivity and power perturbation effects of poison pins in mockups of 17 by 17 fuel assemblies containing 24 pin positions.

This report summarizes the experimental results obtained during the second calendar quarter of 1974. Results obtained during the previous quarter are reported in reference 1. Completed phases of the program are summarized in references 2 through 12.

2. DESCRIPTION OF ASSEMBLY

2.1. Facility

The facility, located at B&W's Lynchburg Research Center, is a critical assembly within an aluminum tank having the following dimensions: diameter 5 ft, height 6.5 ft, wall thickness 0.5 inch. The water-handling equipment, instrumentation, control system, and other auxiliaries are conventional.

2.2. Fuel Rods

The fuel rods are 0.475 inch in diameter by 61.59 inches long. The cladding is type 6061 aluminum, 0.032 inch thick, and the UO_2 fuel is enriched to 2.46 wt % uranium-235. The fuel is described further in reference 1.

2.3. Perturbing Pins

Neutron-absorbing (poison) pins are used to produce lattice heterogeneities for study. The Pyrex* rods contain 12.6 wt % B_2O_3 , are 188 cm long, and have a maxwellian-averaged macroscopic absorption cross section of 3.2 cm^{-1} . These rods are 0.327 inch in diameter and are centered in the grid spaces of the top and bottom grid plates by 0.050-inch-thick rubber sleeves, which slip over the poison rods at the grid plate locations.

The Vicor* rods contain about 3 wt % B_2O_3 in pure silica. Their maxwellian-averaged macroscopic cross section is 0.76 cm^{-1} . Two 3-foot-long rods are loaded into type 6061 aluminum tubes 6 feet long by 0.438 inch OD by 0.035 inch wall. Each tube is sealed at the bottom by a 0.375-inch-thick aluminum plug (welded in place) and at the top by a removable cork plug.

Pertinent parameters and compositions of these perturbing pins are given in Table 2-1.

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*Registered trade marks, Corning Glass Works.

2.4. Core Description

Top and bottom plates align the fuel rods in the core tank. The top and bottom "egg-crate" grid plates are 1-inch-wide, slotted aluminum strips, which are interlocked to form a square matrix. The strips are 0.160 inch thick and are spaced on centers of 0.644 ± 0.002 inch.

Figure 2-1 is a loading diagram of Core XIV. Imaginary lines divide the center of the core into nine identical elements, 17 lattice pitches square. The core is further described in reference 1.

Table 2-1. Physical Properties of Perturbing Pins

<u>Parameter</u>	<u>Pyrex</u>	<u>Clad Vicor</u>
Perturbing medium		
Material	Pyrex glass	Vicor glass
Diameter, cm	0.830 ± 0.001	0.825 ± 0.002
Length, cm	188.0 ± 0.1	183.0 ± 0.3
Mass, g	225.4 ± 0.5	214.5 ± 0.5
Analysis, wt %		
B ₂ O ₃	12.613 ± 0.008	3.035
Boron	3.919	0.943
Cladding		
Material	None	6061 Al
Diameter, cm	--	1.115 ± 0.001
Thickness, cm	--	0.090 ± 0.000

Figure 2-1. Core XIV, Loading Diagram

○ - Water-filled position

● - Perturbing Pin

3. MEASUREMENTS

The best measure of reactivity change is the change in boron concentration of the moderator since this quantity can be readily compared with computer calculations. Therefore, excess reactivity was controlled by dissolving boric acid (H_3BO_3) in the moderator (demineralized water). The boron concentration in parts per million (ppm) is defined as the grams of natural boron per million cubic centimeters (10^6 cm^3) of moderator at 25C; it was determined by titration against a standard KOH solution. The measurements have an absolute standard deviation of ± 3 ppm. The moderator boron concentrations for loadings 4 and 5 are given in Table 3-1. The concentrations listed produce a k_{eff} of 1.0000 when the height of the moderator is 145.0 cm and all safety blades are fully withdrawn.

Radial power distribution measurements were made through one eighth of the central "element." The relative pin powers were determined by counting collimated fission product decay gammas from activated fuel rods with a NaI scintillation counting system. The system was biased to count gamma rays of energies greater than 200 keV. The collimator consisted of a 0.5-inch-wide by 1-inch-long slot in a 2-inch-thick lead shield placed between the fuel rod and the detector, so that only the gammas from a 0.5-inch segment of the rod were counted. The detector was surrounded by 2 inches of lead, and other portions of the fuel rod were shielded from the detector by another 2 inches of lead.

So that activations would be performed at a constant moderator height, the boron concentration was adjusted to make the assembly supercritical and on a reasonable exponential period at a moderator level of 145.0 ± 0.1 cm. The integrated exposures were typically 1 kW-minute. The activated fuel rods were then counted after a 60-minute decay time. The rods were counted at an elevation of 78.7 cm above the reference plane and were rotated while being counted to provide data that are independent of the fuel rod orientation. Counting time varied from 7 to 30 seconds, and the total counts from each rod were approximately 30-45,000 counts. The background activity was kept low by

always loading fuel rods with very low integrated power histories in the positions to be measured.

Decay corrections were obtained from a "master" fuel rod, which was irradiated simultaneously with the rods to be counted and was counted on a second counting system. The electronics and collimation of the second system were similar to those of the first counting system. Counts were taken on the two counting systems simultaneously; during the acquisition of data from a given irradiation, the master fuel rod was never moved. A standard fuel rod was recounted frequently to provide a check on the stability of the two counting systems.

The results of the radial power distribution measurements for loadings 4 and 5 are presented in Tables 3-2 and 3-3. The percentages listed in the power profile tables are standard deviations obtained from two or more measurements.

Table 3-1. Core XIV Loadings Studied During Quarter

	<u>Loading</u>	
	<u>4</u>	<u>5</u>
No. of fuel rods	4736	4736
Perturbing material	Vicor	Pyrex
No. of fuel positions occupied by perturbing material	24	24
Other vacant positions filled with water	201	201
Moderator boron concentration producing critical condition when moderator height is 145 cm, ppm	1246	1204

Table 3-2. Midplane Power Profile - Core XIV, Loading 4

		Distance East of Core Center, pin pitches								
		0	1	2	3	4	5	6	7	8
Distance South of Core Center, pin pitches	0	Water			Vicor			Vicor		
	1	1.816 (0.1%)	1.697 (0.2%)							
	2	1.679 (0.2%)	1.686 (0.2%)	1.628 (0.3%)						
	3	Vicor	1.660 (0.5%)	1.651 (0.9%)	Vicor			Vicor		
	4	1.646 (1.2%)	1.648 (0.1%)	1.668 (0.2%)	1.673 (0.5%)	1.638 (0.1%)				
	5	1.647 (0.1%)	1.656 (0.3%)	1.651 (0.5%)	1.671 (1.6%)	1.666 (0.2%)	Vicor			
	6	Vicor	1.651 (0.2%)	1.670 (0.4%)	Vicor	1.686 (0.1%)	1.683 (0.7%)	1.719 (0.6%)		
	7	1.665 (0.3%)	1.671 (0.3%)	1.654 (0.3%)	1.687 (0.1%)	1.699 (0.4%)	1.638 (0.1%)	1.675 (1.3%)	1.702 (0.6%)	
	8	1.681 (0.1%)	1.666 (0.1%)	1.676 (0.3%)	1.670 (0.7%)	1.696 (0.1%)	1.681 (0.4%)	1.682 (0.4%)	1.676 (0.5%)	1.674 (0.8%)

Table 3-3. Midplane Power Profile - Core XIV, Loading 5

		Distance East of Core Center, pin pitches								
		0	1	2	3	4	5	6	7	8
Distance South of Core Center, pin pitches	0	Water			Small Pyrex			Small Pyrex		
	1	1.389 (0.6%)	1.294 (0.1%)							
	2	1.232 (0.7%)	1.259 (1.0%)	1.218 (1.2%)						
	3	Small Pyrex	1.225 (0.5%)	1.228 (0.8%)	Small Pyrex			Small Pyrex		
	4	1.239 (1.1%)	1.243 (0.9%)	1.260 (0.1%)	1.225 (0.5%)	1.229 (0.1%)				
	5	1.238 (0.7%)	1.284 (0.1%)	1.248 (0.9%)	1.248 (0.4%)	1.241 (0.6%)	Small Pyrex			
	6	Small Pyrex	1.252 (1.0%)	1.280 (0.1%)	Small Pyrex	1.309 (0.9%)	1.289 (1.3%)	1.378 (0.6%)		
	7	1.289 (1.3%)	1.327 (0.9%)	1.322 (0.8%)	1.350 (0.7%)	1.353 (1.0%)	1.372 (0.8%)	1.393 (1.0%)	1.455 (0.6%)	
	8	1.407 (0.2%)	1.373 (1.0%)	1.442 (0.5%)	1.403 (0.2%)	1.409 (0.4%)	1.390 (0.3%)	1.453 (0.4%)	1.414 (0.8%)	1.492 (0.8%)

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