July 1974

PHYSICS VERIFICATION PROGRAM

PART III, TASK 11

Quarterly Technical Report

January-March 1974

by

M. N. Baldwin

MASTER

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AEC Contract No. AT(11-1)-3109

B&W Contract No. 41-2007

(RBE-2561)

Prepared for

THE U. S. ATOMIC ENERGY COMMISSION

by

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ACKNOWLEDGMENT

The author wishes to thank W. T. Hamilton and J. O. Towles for their assistance on this project.

Babcock & Wilcox
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Report BAW-3647-30

July 1974

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Key Words: Critical Assembly, Neutron Absorption
Reactivity Worth, Lumped Burnable Poison

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 of 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 first calendar quarter of 1974. Completed phases of the program are summarized in references 1 through 11.

2. DESCRIPTION OF ASSEMBLY

2.1. Facility

The facility used in Task 11 is located at B&W's Lynchburg Research Center. The critical assembly is erected in a 5-foot-diameter by 6.5-foot-high core tank having 1/2-inch-thick aluminum walls. The water-handling equipment, instrumentation, control system, and other auxiliaries are conventional in design.

2.2. Fuel Rods

Table 2-1 summarizes the physical properties of the fuel rods. The uncertainties are standard deviations of the means obtained from vendors' quality control data and check measurements on 50 to 100 randomly selected samples. The impurities are given as the summation of $N_i \sigma_i$, where N_i is the concentration of each impurity per cubic centimeter of the oxide fuel, and σ_i is the corresponding microscopic absorption cross section at 2200 m/s. The end caps are 1/8-inch-thick aluminum plugs. A 1-inch-long dead space between the top of the fuel pellet stack and the top end cap is filled with Kaowool.

2.3. Perturbing Pins

Poison and vacant water-filled positions are used to produce lattice heterogeneities for study.

The Vicor* rods contain about 3 wt % B_2O_3 in pure silica. Their Maxwell-averaged macroscopic cross section (Σ_a) is 0.76 cm^{-1} . Two 3-foot-long rods are loaded into type-6061 aluminum tubes, 6 feet long by 7/16-inch OD by 0.035-inch wall. Each tube is sealed at the bottom by a 3/8-inch-thick aluminum plug (welded in place) and at the top by a removable cork plug.

*Registered trademark, Corning Glass Works.

The Ag-In-Cd poison pins, 0.400-inch diameter $\times$ 62.03 inches long, are composed of 80 wt % Ag, 15 wt % In, and 5 wt % Cd. Their calculated macroscopic thermal cross section is 13.6 cm^{-1} . The alloy pins are clad with 0.438-inch-OD by 0.016-inch-wall 321 stainless steel. The stainless steel tubes are sealed at the bottom by a 1/8-inch-thick stainless steel end plug (welded in place) and at the top by a removable cork plug.

The B_4C pins are 0.438-inch-OD by 0.035-inch-wall aluminum tubes filled with natural B_4C powder ranging from 30 to 50 mesh. The bottom ends are sealed with welded aluminum plugs, and the tops are sealed with a removable cork plug. The pins contain 156 g of B_4C , which constitutes a column long enough to span the full core height. The space within the tubes above the B_4C is void and extends about 1 foot above the moderator level. The B_4C is compacted to $2.233 \pm 0.003 \text{ g/inch}$.

Pertinent parameters and compositions for the perturbing pins are given in Table 2-2.

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 $0.644 \pm 0.001 \text{ inch}$.

The fuel rods are supported on a 2-inch-thick aluminum base plate, which is raised about 1 inch above the bottom of the 5-foot-diameter tank. The intervening space is filled with moderator. Moderator levels are reported relative to a reference plane at the bottom of the active fuel. Figure 2-1 shows the vertical dimensions of the cores. The fuel rods and perturbing pins are uniformly spaced at intervals of the lattice pitch and are loaded to approximate a cylindrical geometry.

The safety blades are 8-inch-wide boral. Each blade is thin enough to pass between rows of fuel rods, so that uniform lattice spacing can be maintained. During measurements, the safety blades are held in a cocked position to minimize their contribution to core perturbations. Criticality is achieved by raising the level of the moderator. Boric acid is dissolved in the moderator to control excess reactivity.

A loading diagram of Core XIV is shown in Figure 2-2. Imaginary lines divide the center of the core into nine identical elements, 17 lattice pitches square.

Table 2-1. Physical Properties of Fuel Rods

<u>Parameter</u>	<u>Value</u>
Outer diameter, in.	0.4748 ± 0.0006
Wall thickness, in.	0.032 ± 0.001
Wall material	6061 aluminum
Pellet (fuel) diameter, in.	0.4054 ± 0.0005
Total length, in.	61.59 ± 0.16
Active (fuel) length, in.	60.37 ± 0.35
Weight of fuel, g/rod	1305.5 ± 1.0
U/UCO ₂ , wt %	88.13 ± 0.01
Enrichment, ²³⁵ U/U, wt %	2.459 ± 0.002
Weight of ²³⁵ U, g/rod	28.29 ± 0.02
Pellet (fuel) density, g/cm ³	10.24 ± 0.04
$\Sigma \sigma_i$ (summation of impurities), cm ² /cm ³ oxide	$<10^{-3}$

Table 2-2. Physical Properties of Perturbing Pins

Parameter	Vicor	Ag-In-Cd	B ₄ C
Perturbing Medium	Vicor glass	Ag-In-Cd	B ₄ C
Material	0.825 ± 0.002	1.016 ± 0.000	0.935 ± 0.001
Diameter, cm	183.0 ± 0.3	157.6 ± 0.0	177.5 ± 2.0
Length, cm	214.5 ± 0.5	1296 ± 5	156.0 ± 0.1
Mass, g			
Analysis, wt %			
B ₂ O ₃	3.035	-	-
Boron	0.943	-	77.8
Silver	-	79.68	-
Indium	-	15.09	-
Cadmium	-	5.2	-
Carbon	-	-	20.8
Anhydrous B ₂ O ₃	-	-	0.1
Particle size, % 30 to 50 mesh	-	-	91.2
Cladding			
Material	6061 Al	304 SS	6061 Al
Diameter, cm	1.115 ± 0.001	1.120 ± 0.001	1.113 ± 0.001
Thickness, cm	0.090 ± 0.000	0.046 ± 0.000	0.089 ± 0.001

Figure 2-1. Vertical Core Dimensions

Figure 2-2. Core XIV

○ - 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-calculated quantities. 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 10^6 cm³ 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 1 through 4 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.

Table 3-1. Core Loadings Studied During Quarter (All loadings used 4736 fuel rods with 24 positions occupied by perturbing material and 201 other vacant positions filled with water.)

<u>Core</u>	<u>Loading</u>	<u>Perturbing material</u>	<u>Moderator B conc producing critical condition when height is 145 cm, ppm</u>
XIV	1	Water	1289
	2	Ag-In-Cd	1165
	3	B ₄ C	1160
	4	Vicor	1246

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