CRITICAL EXPERIMENTS SUPPORTING CLOSE PROXIMITY WATER STORAGE OF POWER REACTOR FUEL

TECHNICAL PROGRESS REPORT
FOR THE PERIOD
APRIL 1, 1978-JUNE 30, 1978

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Critical Experiments Supporting Close Proximity
Water Storage of Power Reactor Fuel
Technical Progress Report

By: M. N. Baldwin, G. S. Hoovler
R. L. Eng, F. G. Welfare

ABSTRACT

Experimental measurements are being taken on critical configurations of clusters of fuel rods mocking up LWR-type fuel elements in close proximity water storage. The results will serve to benchmark the computer codes used in designing nuclear power reactor fuel storage racks.

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1. INTRODUCTION

In July 1977, The Babcock & Wilcox Company (B&W) was awarded a contract by the U. S. Department of Energy (DOE) to conduct critical experiments supporting close proximity water storage of nuclear power reactor fuel. The need for this program resulted from delays in nuclear fuel reprocessing capability in the United States. These delays have greatly increased the amount of fuel requiring storage and have placed a premium on the optimum use of storage capacity.

Experimental measurements are being taken on critical configurations of fuel rod clusters, mocking up LWR-type fuel elements in close proximity water storage. The square clusters with 14 rods on each side are arranged in 3 by 3 arrays. Both the spacing between the fuel clusters and the intervening material are being varied to provide a variety of benchmark loadings.

The KENO IV code and the PDQ07 code (in selected cases) are being used to analyze each benchmark loading to determine the calculated k_{eff} of each configuration.

All pertinent data will be documented in the final report in sufficient detail to permit use of the benchmark loadings in validating calculational methods according to ANSI Standard N16.9-1975.

Quarterly reports are being issued during the experimental measurement portion of the contract. This report is the third in the quarterly series. Work during the previous quarters is reported in references 1 and 2.

2. DESCRIPTION OF FACILITY

2.1. Facility

The facility, located at B&W's Lynchburg Research Center, is a critical assembly within a core tank 152.4 cm in diameter by 198 cm high having aluminum walls 1.27 cm thick. The facility is further described in reference 1.

2.2. Fuel Rods

The fuel rods are 1.206 cm in outside diameter (OD) and 156.4 cm long. The type 6061 cladding is 0.081 cm thick, and the UO_2 fuel is enriched to 2.46 wt % ^{235}U . The fuel is further described in reference 1.

2.3. B_4C Pins

The B_4C pins are aluminum tubes, 1.113 cm in OD by 0.089 cm thick, filled with natural B_4C powder ranging from 30 to 50 mesh. The pins are further described in reference 2.

2.4. Unit Assemblies

The unit assemblies are 14 by 14 rod assemblies that can be moved as units; and each has its own top, center, and bottom grid plates. Fuel rods occupy 192 of the rod positions, and threaded aluminum rods occupy the corner positions. The lower ends of the threaded rods have fittings which fit into a large bottom grid for alignment. A photograph of a unit assembly is shown in Figure 1.

Each grid plate is a 9.016-inch square 6061 aluminum plate. The bottom, center, and top grids are 1.000, 0.125, and 0.500 inch thick, respectively. All rods are spaced on a square pitch of 0.644 inch. The type 6061 aluminum corner rods of each unit assembly are 0.500 inch in diameter.

Figure 1. Partially Loaded Unit Assembly

3. MEASUREMENTS

The experimental measurements are divided into two parts:

In the first part of the program, the clusters were separated by water only or by water and B_4C -filled pins. Large top and bottom grid plates held the fuel rods and B_4C pins in place. These measurements were completed last quarter. Some preliminary calculations on these cores have been performed and are discussed in section 4.

In the second part of the experimental program, the nine unit assemblies will be separated by water only, by water and stainless steel sheets, and by water and borated aluminum sheets. A difference in the design of the experiment was necessary so that the sheets could be readily changed.

During this quarter we loaded a core composed of nine unit assemblies separated by four pin pitches. This core, which is shown in Figure 2, was found to be subcritical.

Figure 2. Core Comprising Nine Unit Assemblies
Separated by Four Pin Pitches

4. ANALYSIS

This section describes how the benchmark cores were modeled by the KENO IV code. An analysis of the degree to which certain modeling assumptions influence the calculated results is also presented. In a few select cases, certain simplifications made in modeling the core appear to bias the calculated results slightly. We eliminated this potential bias by modeling these cores more precisely.

The neutron multiplication factor (k_{eff}) of each benchmark core was calculated using the monte carlo criticality code KENO IV.³ The 123-group XSDRN cross section set was used.⁴ Resonance self-shielding was accounted for in the uranium-238 isotope only. Self-shielding corrections were made with the NITAWL code from the AMPX package.⁵

The portions of the core that were mocked up by the basic KENO computer model are shown in Figure 4. The fuel rods have an active length of 153 cm. Criticality measurements were taken with all control blades withdrawn to 149 cm above the top of the base plate. For uniformity in reporting, the k_{eff} at a water height of 145 cm was experimentally determined for all cores.

The computer representation explicitly modeled each fuel rod, each B_4C pin, the moderator, and the aluminum tank in the radial (X-Y) direction. Axially, the basic computer model extended from the bottom of the core tank to the surface of the moderator. The fuel and support structure above the water were not represented in the basic computer model.

For certain cases, the calculated differences in reactivity at the critical water height and at a water height of 145 cm (using the basic computer model) were larger than the experimental values. For example, the measured critical water height for core VI (Figure 3) with 0 ppm moderator boron was 107.67 cm. Using the methods described in reference 2, we determined experimentally that the k_{eff} for core VI with 145.0 cm of water would be 1.0098 ± 0.0011 . Thus, the measured Δk associated with increasing the water of core VI from 107.67

cm (the critical condition) to 145 cm was 0.0098 ± 0.0011 . The calculated Δk associated with the same change in water level, however, was 0.015 ± 0.007 . (The error bar represents one standard deviation.) These calculations were made using the basic computer model, in which all material above the water was ignored. Although the calculated and experimental values for Δk overlap, we suspected that a small bias was introduced by ignoring the dry fuel above the water in the 107.67-cm case. Accordingly, we repeated the calculation, this time including the fuel between 107.67 and 145.0 cm in our computer model.

We modeled the dry fuel above the moderator in two ways. In the first approach, we used KENO's hemicylindrical reflector option. Extending the fuel height to 145 cm with this model (maintaining the moderator level at 107.67 cm) required increasing the height of the water reflector to 145 cm as well. The worth of the extended water reflector was estimated by comparing the calculated k_{eff} of the 107.67-cm core with the extended reflector (basic computer model) to the calculated k_{eff} of the 107.67-cm core without the extended reflector (basic computer model, 107.67-cm reflector). The calculated Δk using this approach was 0.011 ± 0.007 , essentially equal to the experimental value of 0.0098 ± 0.0011 .

In a second, more direct, approach of modeling the extended fuel in KENO, we replaced the hemicylindrical boundary with a linear (zig-zag) approximation. Comparing the model with 145.0 cm of fuel and 107.67 cm of water to the model with 145.0 cm of water and fuel, we obtained a calculated Δk of 0.009 ± 0.007 , also essentially equal to the experimental value of 0.0098 ± 0.0011 .

In all cases for which we modeled the structure (grid, control rods, etc.) above the moderator, the change in k_{eff} was imperceptible.

In summary, when the moderator level is much less than 145.0 cm, ignoring the dry fuel in the core model may bias the calculated results slightly. We can eliminate this potential bias by modeling the dry fuel for these select cases. In no case have we found that the structure above the moderator makes a contribution to neutron multiplication that is perceptible by the KENO code. As such, the calculated results would not be biased by assuming in the computer model that this volume is void.

Figure 3. Core VI Loading Diagram — Nine Arrays
With Two-Pin-Pitch Separation and
64 B₄C Pins

Figure 4. KENO Model of DOE Critical Experiments

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