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EVALUATION OF THE ^{252}CF -SOURCE-DRIVEN NEUTRON NOISE ANALYSIS METHOD
FOR MEASURING THE SUBCRITICALITY OF LWR FUEL STORAGE CASKS

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J. T. Mihalczo

DE87 011112

Instrumentation and Controls Division
Oak Ridge National Laboratory*
Oak Ridge Tennessee 37831-6010

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The ^{252}Cf -source-driven neutron noise analysis method was evaluated to determine if it could be used to measure the subcriticality of storage casks of burnt LWR fuel submerged in fuel storage pools, fully loaded and as they are being loaded. The motivation for this evaluation was that measurements of k_{eff} would provide the parameter most directly related to the criticality safety of storage cask configurations of LWR fuel and could allow proper credit for fuel burnup without reliance on calculations. This in turn could lead to more cost-effective cask designs.

Evaluation of the method for this application was based on (1) experiments already completed at a critical experiments facility using arrays of PWR fuel pins typical of the size of storage cask configurations, (2) the existence of neutron detectors that can function in shipping cask environments, and (3) the ability to construct ionization chambers containing ^{252}Cf of adequate intensity for these measurements. These three considerations are discussed below.

Previous experiments have been performed at the Babcock and Wilcox Critical Experiments Facility with a PWR lattice of LWR fuel pins having a diameter of 5 ft and a borated water moderator and reflector.¹ The application of this method to a 5-ft-diam configuration of PWR fuel elements is well understood. In these experiments boron concentration was varied from 1.5 to 4.3 g/liter for the full tank of fuel elements, and the number of fuel elements was varied from 4971 to 269 for a boron concentration of 1.5 g/liter. The ^{252}Cf -source-driven neutron noise analysis method satisfactorily measured values of k_{eff} . These experiments showed that experiments with the ^{252}Cf located in the center of the configuration and the detectors in the water reflector at the outer edge of the fuel can be interpreted using point kinetics to obtain the value of k_{eff} .

A high sensitivity uranium fission chamber has been developed by Reuter Stokes, Inc., under a Small Business Innovative Research Program

of the U.S. Department of Energy.² This fission chamber is 8 ft long, can operate in gamma fields of 10^7 R/h, and can detect neutrons with adequate gamma discrimination for these measurements. With appropriate electronics this detector can also operate as a position-sensitive detector having a resolution of 1 ft (i.e., the chamber can be divided into eight 1-ft-long sections and events recorded separately for each of the sections). This feature allows each section to be an independent detector that can be used to investigate axial variations of the count rate. One chamber has been designed, fabricated, and successfully tested by Reuter Stokes, Inc. This chamber is ideally suited for fuel storage cask applications.

The ^{252}Cf source intensity required for cask measurements is reasonable. A ^{252}Cf ionization chamber operating in the current mode and containing ~ 100 μg of ^{252}Cf will be adequate for measurements of a storage cask loaded with PWR fuel that has a burnup of $\sim 35,000$ MWD/MTU and has been out of the reactor for ~ 6 years. This source will be $\sim 10\%$ of the inherent neutron source of a cask of 21 PWR fuel elements. By locating this source in the central fuel element of the cask, the neutrons from the ^{252}Cf will be more effective in producing fissions in the fuel than would the uniformly distributed inherent neutron source of the fuel. Measurements have been performed successfully with ^{252}Cf sources as low as 20% of the inherent source. The reactor physics treatment of this effect is well understood, and the main effect on the measurement is a slight increase in the measurement time.

Based on the above considerations, measurements of the k_{eff} of fuel storage casks such as the CASTOR-V/21³ and the Westinghouse MC-10 appear feasible. For such measurements, the ^{252}Cf source would be fabricated as a ~ 2 -ft-long thin annular fission chamber to fit into the center of the central PWR fuel element. The uranium fission chambers would be located at the outer surface of the fuel, 180° apart and each adjacent to the outer fuel elements. For these experiments the lid would be removed, the source and fission chamber appropriately located, and the cask flooded with water. The cask also could be surrounded by water if

necessary by fabricating a water tank around the cask. Thus, the experiment could be performed at the existing storage locations of the casks or as they are loaded in a fuel storage pool.

The conclusion of this evaluation is that cask measurements are feasible and that measurements under the conditions discussed above would demonstrate the ability to measure k_{eff} for storage casks in highly reactive conditions--fully loaded with fuel, internally flooded with water, and water outside the cask. These measurements would also provide benchmarks for calculations. Thus, by measuring k_{eff} directly, proper credit for fuel burnup could be achieved. This could lead to more cost-effective storage cask designs--designs whose criticality safety is verified by measurements.

References

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