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# POWER SPECTRAL DENSITY MEASUREMENTS WITH $^{252}$CF FOR A LIGHT WATER MODERATED RESEARCH REACTOR

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A method of determining the reactivity of far subcritical systems from neutron noise power spectral density measurements with $^{252}$Cf has previously been tested in fast reactor critical assemblies:[1] a mockup of the Fast Flux Test Facility reactor and a uranium metal sphere. Calculations indicated that this measurement was feasible for a pressurized water reactor (PWR).[2]

The advantage of this method of reactivity determination over other methods is that it determines the reactivity from known or measured properties of the reactor only at the subcritical state of interest; therefore, it does not require calibration near delayed criticality as other methods do. Thus, it can be used in the initial fuel loading of a reactor (where calibration is not available) to determine the subcritical reactivity as the initial fuel loading proceeds. Knowledge of the subcritical reactivity that would be provided by the $^{252}$Cf method while the initial loading proceeds would enhance the safety of the fuel loading and could result in a decrease in the time required to complete the loading.

In order to evaluate the ability to perform these measurements with moderated reactors which have long prompt neutron lifetimes, measurements

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were performed with a small plate-type research reactor whose neutron lifetime (57 microseconds) was about a factor of three longer than that of a PWR and ~50% longer than that of a boiling water reactor. Since the measurement time for a given precision in the spectral densities is proportional to the neutron lifetime (i.e. inversely proportional to the bandwidth over which the spectral densities can be measured), these experiments are severe tests of the feasibility to perform such measurements in a light water reactor. This paper presents the results of the first measurements of power spectral densities with $^{252}Cf$ for a water moderated reactor.

The reactor, the Pool Critical Assembly[3] (PCA), is a light water moderated and reflected research reactor facility at the Oak Ridge National Laboratory in which newly fabricated fuel elements for the Oak Ridge Research Reactor (ORR)[4] were assembled to delayed criticality. The assembly configuration consisted of a 3 × 5 array of fuel elements with 2 additional fuel elements centered on one of the long sides. Four control rods were located at the corners of a 3 × 3 array at one end of the larger array. The uranium was enriched to 93.2 wt% $^{235}U$ and the core consisted of 12 ORR fuel elements (240 grams of $^{235}U$ each) and 5 control rod elements (90 grams of $^{235}U$ each). One 90 gram element (in the center of the 3 × 3 array) contained the $^{252}Cf$ in a 2.5-cm-diameter parallel plate ionization chamber at the horizontal midplane. A pair of detectors was located in a vertical aluminum pipe at the core-reflector boundary above and below the horizontal midplane. The pipe was located adjacent to the central row of 5 fuel elements at the end away from the control rods.

The measurement of the cross power spectral densities of the two detectors with the $^{252}Cf$ source (75,000 fissions/second), $G_{12}$ and $G_{13}$, and

with each other, $G_{23}$, as well as the auto power spectral densities $G_{11}$, allows the determination of the ratio of spectral densities $G_{12}^{*}\ G_{13}/G_{11}\ G_{23}$. This ratio of spectral densities is proportional to $\Delta k/k$. Typical cross power spectral densities (corrected for the frequency response of the measurement system) from measurements with $^{3}He$ proportional counters ($\sim$30 counts per nv-thermal) are shown in Fig. 1 for the 3 × 5 core with one control rod inserted. Measurements were also performed with Lithium glass scintillators operated both in the current and pulse modes, and $^{235}U$ fission counters ($\sim$0.8 counts per nv-thermal). All types of detectors gave the same ratio of spectral densities, as had been the case in previous measurements with fast assemblies and as was theoretically expected. The measurement times for determination of reactivity to ±10% with $^{3}He$ detectors varied from $\sim$6 minutes at $\sim$4 dollars subcritical to about 1 hour at $\sim$21 dollars subcritical for the-all-rods-in case with two fuel elements removed. The coherence as a function of reactivity is shown in Fig. 2. As predicted by the theory, the coherence for the CPSD of one detector with Cf is not as strong a function of reactivity as that between both detectors. The error in a spectral density is inversely proportional to the coherence for small coherence values.

These measurements show that this method of subcriticality determination is practical for light water reactors. For detector efficiencies characteristic of existing detectors, these spectral density measurements with $^{252}Cf$ can be performed in the initial loading of light water reactors without significantly increasing the loading time and may enhance the safety of the loading. For applications with higher gamma radiation such

as refueling, storage facilities, or post accident situations, measurements would take longer since less sensitive detectors which operate in high radiation fields would be required.

## REFERENCES


1. J. T. Mihalczo, V. K. Paré, G. L. Ragan, M. V. Mathis and G. C. Tillet, "Determination of Reactivity from Power Spectral Density Measurements with Californium 252", *Nuclear Science and Engineering*, 66, 29-59 (1978).
2. J. T. Mihalczo and V. K. Paré, "Feasibility of Reactivity Determination from Neutron Noise Spectral Density with $^{252}Cf$ in the Initial Loading of Light Water Moderated Reactors", *Trans. of the ANS*, 28, 799-800 (1978).
3. L. E. Stanford, *Description and Safety Analysis of the Pool Critical Assembly*, ORNL/TM-3035 (1970).
4. T. P. Hamrick and J. H. Swanks, *The Oak Ridge Research Reactor - A Functional Description*, ORNL-4169 (Vol. 1) (1968).

## FIGURE CAPTIONS

Fig. 1. CPSDs from measurements with $^3$He proportional counters on a light water moderated research reactor with one of the corner control rods inserted. (~$1.2 subcritical)

Fig. 2. Coherence amplitude ($\omega < \alpha$) as a function of reactivity from spectral density measurements with $^3$He detectors for a light water moderated research reactor.