CONF-850610--39

^{252}CF-SOURCE-DRIVEN NEUTRON NOISE ANALYSIS MEASUREMENTS FOR COUPLED URANIUM METAL CYLINDERS

J. T. Mihalczo, W. T. King, and E. D. Blakeman

Oak Ridge National Laboratory*
Oak Ridge, Tennessee 37831

CONF-850610--39

DE85 016412

Summary of Paper to be Presented at
The 1985 Annual Meeting of the
American Nuclear Society
Boston, Mass., June 9-14, 1985

*Operated by Martin Marietta Energy Systems, Inc., for the U.S. Department of Energy under Contract No. DE-AC05-84OR21400.

The ^{252}Cf-source-driven neutron noise analysis method[1] for obtaining the subcriticality of an assembly of fissile material from cross-power spectral densities (CPSDs) was developed to avoid some difficulties inherent in other measurement methods. This method requires measurement of frequency-dependent CPSD $G_{23}(\omega)$ between a pair of detectors (Nos. 2 and 3) in or near the fissile assembly and CPSDs $G_{12}(\omega)$ and $G_{13}(\omega)$ between these detectors and a source of correlated neutron noise from an ionization chamber (No. 1) containing ^{252}Cf, also in or near the fissile assembly. Also, the auto-power spectral density $G_{11}(\omega)$ of the source is required. The ratio of spectral densities $G_{12}^{*}G_{13}/G_{11}G_{23}$ is then formed and is related to the subcriticality. The method has a variety of potential applications: (1) initial fuel loading in a wide variety of reactors, (2) refueling of reactors, (3) fuel preparation facilities, (4) fuel processing facilities, (5) fuel storage facilities, (6) zero-power testing of reactors, (7) post-accident situations, and (8) verification of calculational methods for assemblies with $\kappa < 1$. To date various measurements have been performed which demonstrate the usefulness of the method including measurements with single uranium metal cylinders.[1-7] The experiments described here, which used coupled uranium (93.15 wt% ^{235}U) metal cylinders separated by air, are the first application of this method to coupled systems.

This method has some unique features that make it useful for studying the interaction in coupled systems. By locating the source on one cylinder and the detector on the other cylinder, or each of the detectors on a different cylinder, the CPSDs G_{12}, G_{13}, and G_{23} will arise from fission chains propagated by neutrons traveling between cylinders.

Thus, for these detector source locations, as the coupling between cylinders goes to zero for large distances so will the CPSDs.

The uranium metal and the apparatus used for these experiments has been described previously.[1,8,9] Each of the two coaxial 7-in.-diam right circular cylinders were 2.00 in. thick, and the spacing between the flat surfaces of the cylinders varied up to 6 in. The ^{252}Cf source was centered on the outer flat surface of one cylinder and the detectors (Li glass scintillators) were located in three configurations: (1) one detector adjacent to the radial surface of each cylinder, (2) both detectors (180° apart) adjacent to the radial surface of the cylinder with the ^{252}Cf source, and (3) both detectors (180° apart) adjacent to the radial surface of the cylinder without the ^{252}Cf source. The uranium cylinders with zero spacing comprised a single 4-in.-thick cylinder for which a measurement had been performed in 1975.[1] The previous measurements were performed with a 0.07-μg ^{252}Cf source while those in this work were performed with a 0.20-μg ^{252}Cf source. The measured ratios of spectral density were 0.069 (1975) and 0.067 (1984) and thus demonstrated the method's reproducibility even though the sources and detectors were different.

The measured ratio of spectral densities is plotted as a function of spacing between the cylinders in Fig. 1 for two locations of the source and detectors: both detectors adjacent to the cylinder with the ^{252}Cf source, and both detectors adjacent to the cylinder without the ^{252}Cf source. As the spacing between cylinders increases, the coupling between cylinders decreases and the number of fission chains propagating

between cylinders decreases. For the experiments with the source adjacent to one cylinder and the detectors adjacent to the other, this has the effect that CPSDs G_{12} and G_{13} decrease, and thus the ratio of spectral densities decrease with increased spacing since G_{23} does not go to zero for less coupling. The neutron multiplication factor, k_{eff}, was obtained from the ratio of spectral densities from measurements with the source and detectors adjacent to the same disk using a simple point kinetics interpretation without correction for spatial effects. This neutron multiplication factor is compared with that calculated using the DOT[10] transport method and the KENO[11] Monte Carlo method using the ENDF/B-IV cross-section library (Fig. 1). The measured and calculated results agree within 2% for separations up to 5 in. With these locations for source and detectors, the subcriticality of one cylinder as affected by the proximity of the other is measured. With the source and/or detectors on different cylinders, a simple point kinetics interpretaion of the ratio of spectral densities will not give the subcritical value. For locations where the source and detector are not on the same cylinder, a kinetics model which incorporates the lumped nature of the system will be required to interpret the ratios of spectral densities to obtain the correct subcritical value for the system; coupled core kinetics[12] is required for these source-detector locations.

These experiments demonstrate the usefulness of the method for (1) obtaining the subcritical neutron multiplication factor for a coupled system, (2) measuring the neutron multiplication factor for systems with k_{eff} <0.8, and (3) studying the details of the coupling

between units by location of the source and detectors on different cylinders.

Fig. 1. Ratio of spectral densities versus distance between uranium metal cylinders separated in air.

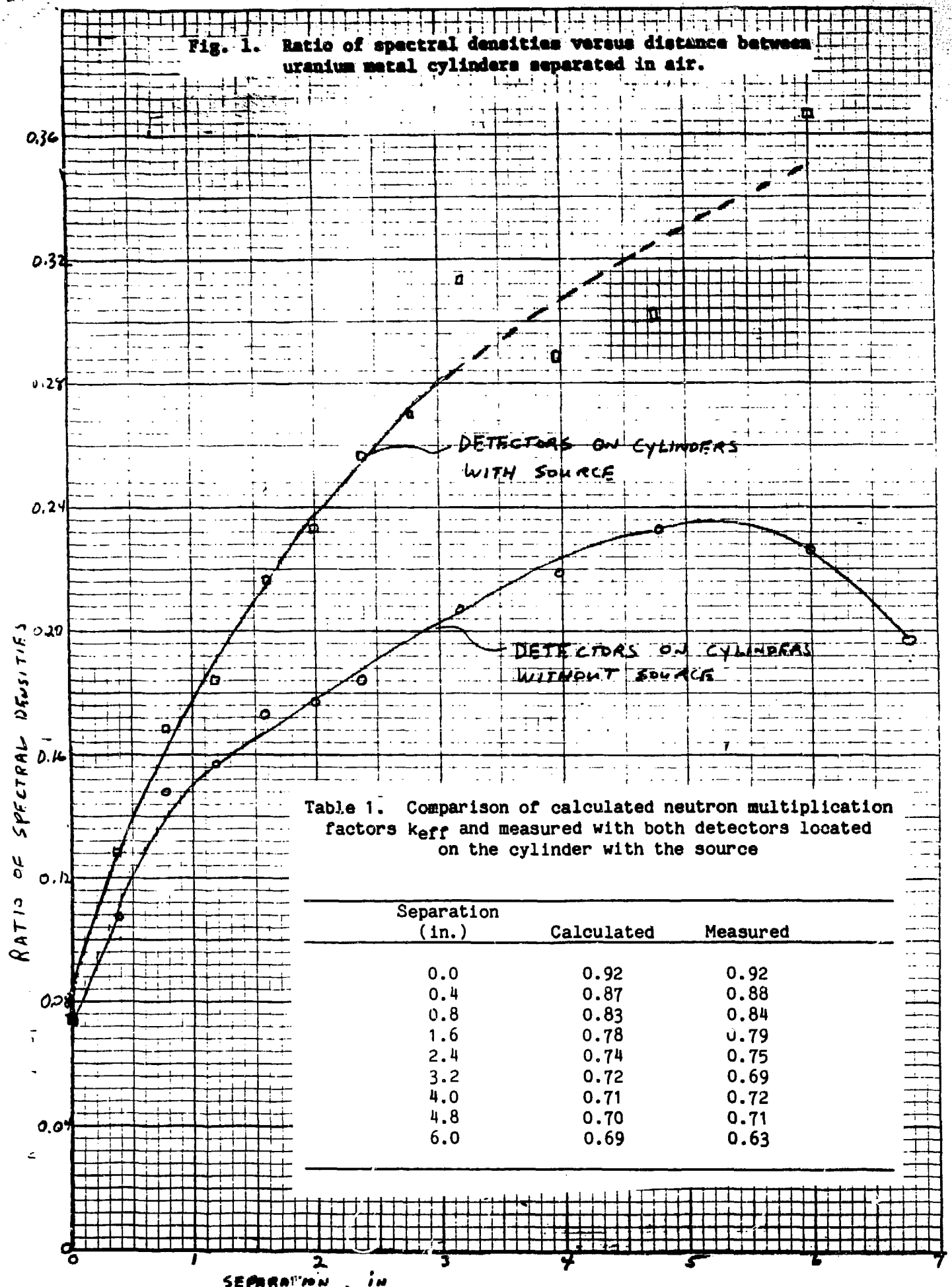

Table 1. Comparison of calculated neutron multiplication factors k_{eff} and measured with both detectors located on the cylinder with the source

Separation (in.)	Calculated	Measured
0.0	0.92	0.92
0.4	0.87	0.88
0.8	0.83	0.84
1.6	0.78	0.79
2.4	0.74	0.75
3.2	0.72	0.69
4.0	0.71	0.72
4.8	0.70	0.71
6.0	0.69	0.63

REFERENCES

1. J. T. Mihalczo, V. K. Pare, G. L. Ragan, M. V. Mathis, and G. C. Tillett, "Determination of Reactivity from Power Spectral Density Measurements with ^{252}Cf," Nucl. Sci. Eng. 60, 29 (1978).

2. W. T. King and J. T. Mihalczo, "Power Spectral Density Measurements with ^{252}Cf for a Light-Water-Moderated Research Reactor," Trans. Am. Nucl. Soc. 33, 796 (1979).

3. J. T. Mihalczo, R. C. Kryter, and W. T. King, "Preliminary Investigation of ^{252}Cf-Driven Neutron Noise Analysis for Subcritical Fuel Solution Systems," Trans. Am. Nucl. Soc. 38, 359 (1981).

4. J. T. Mihalczo, W. T. King, E. B. Johnson, and E. D. Blakeman, "Subcriticality Measurements for a Fuel Solution Tank with Changing Fuel Concentration Using ^{252}Cf-Source Driven Neutron Noise Analysis," Trans. Am. Nucl. Soc. 45, 337-38 (1983).

5. S. J. Raffety and J. T. Thomas, "Experimental Determination of Safe Handling Procedures for HFIR Fuel Elements Outside the Reactor," ORNL/TM-1488, Oak Ridge National Laboratory (July 1966).

6. J. T. Mihalczo and W. T. King, "^{252}Cf-Source-Driven Neutron Noise Method for Measuring Subcriticality of Submerged HFIR Fuel Elements," Trans. Am. Nucl. Soc. 43, 408 (1982).

7. W. T. King, J. T. Mihalczo, and E. D. Blakeman, "Preliminary Investigation of the ^{252}Cf-Source-Driven Noise Analysis Method of Subcriticality Measurement in LWR Fuel Storage and Initial Loading Applications," Trans. Am. Nucl. Soc. 47, 239-40 (1984).

8. J. T. Mihalczo, Nucl. Sci. Eng. 37, 292-302 (1968).

9. J. T. Mihalczo, Prompt Neutron Decay in a Two Component Enriched Uranium Metal Critical Assembly, ORNL-TM-470 (1963).

10. W. A. Rhoades, D. B. Simpson, R. L. Childs, and W. W. Engle, Jr., The DOT-IV Two-Dimensional Discrete Ordinates Transport Code with Space-Dependent Mesh and Quadrature, ORNL/TM-6529 (1979).

11. L. M. Petrie and N. F. Cross, KENO IV: An Improved Monte Carlo Criticality Program, ORNL-4938 (1975).

12. R. Avery, Theory of Coupled Reactors, Proc. Geneva Conf., 12:182 (1958).