DECOUPLING OF URANIUM METAL WITH BORATED PLASTER USING ^{252}Cf NOSE ANALYSIS METHODS

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The use of borated plaster to isolate uranium (93.2 wt% ^{235}U) metal was studied in a series of subcritical experiments with uranium metal cylinders (7.0 in. diam, 2.0 in. thick) and slabs (~1.4 × ~5.4 × ~10.1 in. dimensions). In the cylindrical experiments, the thickness of borated plaster was varied up to 10 in. and the subcriticality measured using the ^{252}Cf-source-driven neutron noise analysis method.[1] In the experiments with the uranium slabs, an array of slabs 3 wide and 8 high was assembled in steps to demonstrate the subcriticality of this array with 3.75-in.-thick borated plaster as an isolating material between all uranium slabs. In the slab experiments, both noise analysis and source neutron multiplication measurements were performed. Before assembly of the slab array the presence of boron in the plaster was verified by neutron transmission and gamma-ray spectrometry measurements.

Previous measurements demonstrated the usefulness of the ^{252}Cf-source-driven neutron noise analysis method for determining the subcriticality of coupled uranium metal cylinders in air.[2] In the cylindrical experiments reported here, borated plaster was located between the flat surface of two coaxial, 2-in.-thick right circular cylinders. The borated plaster has a density of 1.3 g/cc with a boron density of 0.08 g/cc and a hydrogen content 45% that of water at room temperature. In Fig. 1 the ratios of cross- and auto-power spectral densities, $G^*_{12}G_{13}/G_{11}G_{23}$, from which the subcriticality is determined, are plotted as a function of borated plaster thickness for two locations of the source (subscript 1) and detectors (subscripts 2 and 3). The source provides neutrons to initiate the fission chain multiplication process, and the detectors detect particles from the induced fissions. As with previous measurements with coupled uranium metal cylinders in air, the ratio of spectral densities depends on the location of the source and detectors.[2] With the source and detectors on different cylinders, G_{12} and G_{13} approach zero as the coupling goes to zero and a spatial kinetics model is required to obtain the subcriticality and coupling reactivities from these measurements. However, with the sources and detectors located adjacent to the same cylinders, the subcriticality can be obtained from the measured ratio of spectral densities using a simple point kinetics interpretation of the data. These neutron multiplication factors from measurements are also compared with the results of calculations in Fig. 1. The calculations utilized the DOT transport and KENO Monte Carlo codes with an ENDF/B-IV cross-section library. The measured and calculated neutron multiplication factors agree within ~1%. The experiments showed that a 5-in. thickness of borated plaster effectively decouples uranium metal; that is, the contribution to K_{eff} from interaction is less than 1%.

Comparing the subcriticality from these measurements with borated plaster between uranium to previous measurements with uranium cylinders separated in air, it was found that the neutron multiplication factors are increased by inserting borated plaster between cylinders for all separations of cylinders and thicknesses of borated plaster. For large separations this is obvious, since in the void case large separation results in an unreflected, 2-in.-thick cylinder, and with the borated plaster, large separation results in a 2-in.-thick cylinder reflected by borated plaster on one flat surface. For smaller separations the balance between leakage, slowing down of neutrons by the moderation of the plaster, and absorption by the boron apparently is such that the neutron multiplication factor increases as borated plaster is inserted between uranium cylinders.

Before proceeding with the assembly of the 3 × 8 array of uranium slabs, gamma-ray spectrometry measurements of the neutron capture gamma-rays in boron and neutron transmission measurements with the borated plaster of the array and known samples confirmed the presence of boron in the borated plaster around every slab location in the array. The array was loaded symmetrically from the center outward with the plane of the slabs horizontal. The ratio of spectral densities and relative source neutron multiplication are plotted in Fig. 2 as a function of the number of slabs loaded. The insensitivity of the data to the addition of slabs after the first nine are loaded suggests that the interaction is significant only between adjacent units. The measurements with the borated plaster between the uranium cylinders suggested that the removal of borated plaster from the array might not change the neutron multiplication factor significantly. This was indicated by calculations in which the calculated neutron multiplication factor increased from 0.75 to 0.79 with the borated plaster removed from the array. The use of borated plaster in this case can create a criticality safety problem if the boron is removed.

The experiments with the cylinders showed that the insertion of borated plaster between 7-in.-OD, 2-in.-thick cylinders increases the neutron multiplication factor for all thicknesses of borated plaster and that the approximately infinite isolation thickness of borated plaster is ~5 in. (although decreases in the coupling were measured up to 7.2 in.). The experiments with the 3 × 8 array of uranium slabs showed that the interaction is significant only between adjacent slabs. In addition, the experiments with the cylinders demonstrate the usefulness of the noise analysis measurement method in (1) characterizing the neutronic isolation properties of borated plaster with uranium metal, (2) benchmarking calculations with subcritical experiments, (3) studying the details of the coupling between fissile materials by locating the source and detectors on different cylinders, and (4) determining the subcritical multiplication factor for configurations of uranium and borated plaster to K_{eff} as low as ~0.72.

References

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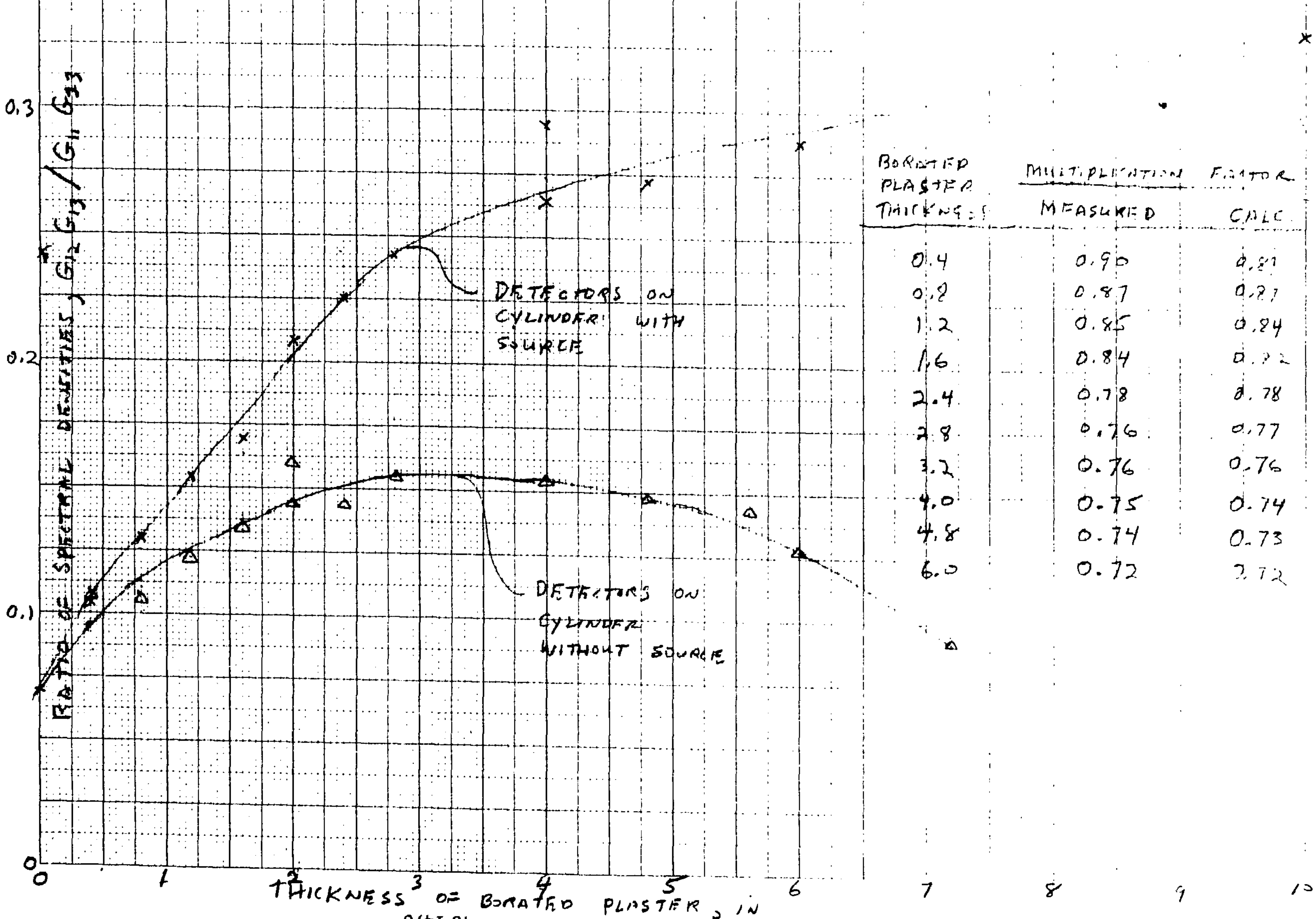
FIG 1 RATIO OF SPECTRAL DENSITIES VERSUS THICKNESS OF BORATED PLASTER BETWEEN URANIUM CYLINDERS



BORATED PLASTER THICKNESS	MULTIPLICATION FACTOR MEASURED	MULTIPLICATION FACTOR CALC.
0.4	0.90	0.81
0.8	0.87	0.81
1.2	0.85	0.84
1.6	0.84	0.82
2.4	0.78	0.78
2.8	0.76	0.77
3.2	0.76	0.76
4.0	0.75	0.74
4.8	0.74	0.73
6.0	0.72	0.72

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FIG 2. RATIO OF SPECTRAL DENSITIES AND RELATIVE SOURCE NEUTRON MULTIPLICATION VERSUS NUMBER OF URANIUM SLABS IN A 3 x 8 ARRAY