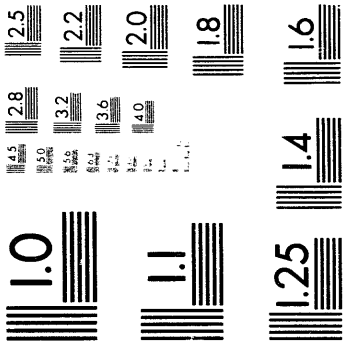
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^{252}Cf-SOURCE-DRIVEN NOISE ANALYSIS MEASUREMENTS FOR CHARACTERIZATION OF CONCRETE HIGHLY ENRICHED URANIUM (HEU) STORAGE VAULTS

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T. E. Valentine[1]
J. T. Mihalczo

Instrumentation and Controls Division
Oak Ridge National Laboratory[2]
Oak Ridge, Tennessee 37831-6010

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The ^{252}Cf-source-driven noise analysis method[1-2] has been used in measurements for subcritical configurations of fissile systems for a variety of applications. Measurements of 25 fissile systems have been performed with a wide variety of materials and configurations. This method has been applied to measurements for (1) initial fuel loading of reactors,[3] (2) quality assurance of reactor fuel elements,[4] (3) fuel preparation facilities,[5] (4) fuel processing facilities,[6] (5) fuel storage facilities,[7] (6) zero-power testing of reactors,[8] and (7) verification of calculational methods for assemblies with the neutron $k < 1$.[9] These previous measurements, performed with a wide variety of multiplying systems, demonstrated the usefulness of the method. The high sensitivity of noise-measured parameters to small changes in fissile systems has been observed in several measurements. This high sensitivity has been evaluated using Monte Carlo neutron transport methods for an array of light-water reactor spent fuel[10] and aqueous solutions of fissile material.[11] Monte Carlo calculations of these noise-measured parameters for a highly enriched uranium (HEU) storage vault were performed to evaluate whether a subcriticality measurement with existing ^{252}Cf source and commercially available detectors was feasible and to determine if the measurement could characterize the ability of the concrete to isolate the fissile material.

The concrete storage vault used for this analysis was a $3\times10\times3$ array of 20-kg castings of HEU material with a ^{235}U enrichment of 93.2 wt %. The castings were isolated by 30.48 cm of concrete in the x-and z-directions and were spaced in air 13.3 cm in the y-direction. The ^{252}Cf source for the measurement was in the central position of the array. Three 1524-mm-long, 50.8-mm-diam ^{3}He proportional counters were located in concrete vault locations on each side of the array and centered in the y-direction of the array. Three detectors with their signals summed were considered as a detector channel.

These calculations of the noise-measured parameters used a variant of the KENO Va Monte Carlo neutron transport code (KENO-NR)[12] for a Sun workstation and the Hansen-Roach cross sections.[13] Approximately 10^6 Cf fissions (3.77 neutrons/fission) were utilized to obtain the desired precision of the noise-measured parameters. Four calculations were performed with varying amounts of unbound water in the concrete: dry concrete, 33% wet, 66% wet, and wet concrete that corresponds to original poured concrete after hardening. In the calculation, the time series of pulses at the detectors from each ^{252}Cf fission were superimposed consistent with a Cf fission rate to obtain the time sequences of detector pulses. These sequences were sampled and Fourier-processed to obtain the autopower spectral densities (APSDs G_{11}, G_{22}, and G_{33} where subscript 1 signifies the ^{252}Cf ionization chamber and 2 and 3 designate the ^{3}He detector channels on each side of the 3×10×3 array); the cross-power spectral densities G_{12}, G_{13}, and G_{23}; the coherences (12, 13, and 23); and the ratio of spectral densities, $G^*_{12}G_{13}/G_{11}G_{23}$.

Table 1 gives a summary of the results of these calculations, and Fig. 1 plots some selected noise-measured parameters as a function of frequency. The neutron multiplication factor changes ~8%, while the ratio of spectral densities changes ~60% from dry to wet concrete. The ratio of spectral densities is eight times more sensitive to changes in the wetness of the concrete than the neutron multiplication factor. The increased sensitivity is expected because the ratio of spectral densities is proportional to $(1-k)/k$. The coherences at low frequencies are given in Table 1 and are plotted as a function of frequency in Fig. 1. The upper plot shows the coherence between the ^{3}He proportional counters on one side of the array and the ^{252}Cf source. The lower plot shows the coherence between the ^{3}He proportional counters on each side of the array. As Fig. 1 shows, the coherences are very sensitive to changes in the water content of the concrete and the coherence between detectors changes approximately a factor of 100 from dry to wet concrete. The extremely high sensitivity of this coherence between detectors means that a measurement of this coherence can be used to determine the unbound water content of the concrete.

The high sensitivity of the noise-measured parameters to the composition of the concrete in HEU metal storage vaults makes this measurement technique a useful way to monitor and assess the criticality safety of HEU storage vaults. In addition to providing the subcriticality (or criticality margin), the isolation characteristics of the concrete can be measured in new or existing HEU storage vaults, and subsequent measurements can be used to assess changes in concrete composition or the criticality safety margin.

Table 1. Calculated neutron multiplication factors and noised-measured parameters for a $3 \times 10 \times 3$ array of highly enriched uranium metal castings in a storage configuration for various amounts of unbound water in concrete

Calculated parameter	Dry	33% Wet	66% Wet	Wet
Neutron multiplication factor	0.875 ± 0.001	0.846 ± 0.001	0.824 ± 0.001	0.808 ± 0.002
Coherence 12 $\times 10^{-3}$	22.5 ± 0.3	12.3 ± 0.1	7.1 ± 0.4	4.2 ± 0.3
Coherence 23 $\times 10^{-4}$	107.0 ± 1.2	21.8 ± 0.6	5.6 ± 0.2	1.4 ± 0.1
Ratio of spectral densities $\times 10^{-4}$	2174 ±12	2680 ± 27	3034 ± 31	3484 ± 56

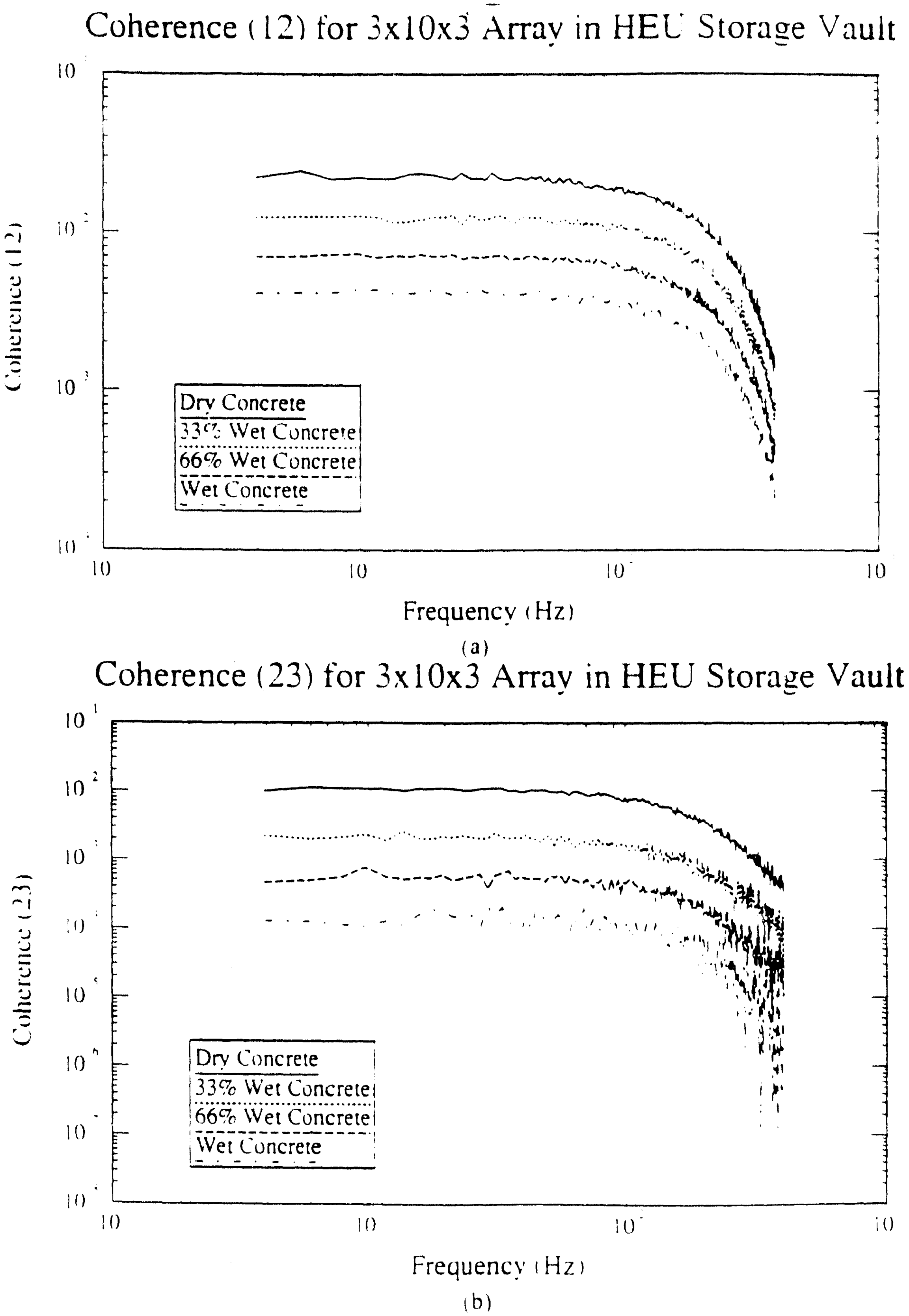

Figure 1. (a) Coherence 12 and (b) Coherence 23 versus frequency for the varying degrees of unbound water content of the concrete.

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