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INFLUENCE OF FUEL VIBRATION ON PWR NEUTRON NOISE ASSOCIATED WITH CORE BARREL MOTION*

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by

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Introduction

Ex-core neutron detector noise has been utilized extensively to monitor core support barrel (CSB) vibrations.[1,2] Previous studies[3,4] have found that only moderate increases in neutron noise normally occur over a fuel cycle in the frequency ranges associated with CSB motion. In order to observe long-term changes in the neutron noise under varying conditions, noise signals at Sequoyah-1, a Westinghouse 1150 Mw(e) pressurized water reactor (PWR), were monitored continuously during the entire first fuel cycle and approximately three months of the second fuel cycle.

Data Acquisition

Noise signals from four lower-half (1.8 m long) ex-core, power-range ionization chambers were monitored and cataloged continuously using a mini-computer-based data acquisition system.[5] The system performed on-line sampling and Fourier analysis of the noise signals. The resulting power spectral densities (PSDs) were cataloged along with 16 operating parameters (reactor power, coolant temperatures, etc.) describing plant conditions. Also, 14-track, FM, analog tape recordings of noise signals were obtained each month and analyzed off-line in order to calculate cross-power spectral densities (CPSDs), which were not available in the on-line system.

Observations

PSDs and CPSDs of the neutron noise exhibit a resonance at a frequency of approximately 6.7 Hz. Phases between the cross-core detectors at this frequency are always 180° and the coherence is always greater than 0.8, thereby indicating pendular CSB motion. Another resonance at 8.0 Hz, having the same coherence and phase relationships can also be resolved in the PSDs and CPSDs at the beginning of the first fuel cycle. This resonance occurs at approximately the second mode of fuel assembly vibration (the first mode occurrs at 3.6 Hz) as deduced from previous studies[6] and in-core neutron noise measurements made at Sequoyah-1. The fuel assembly fundamental mode decreased in frequency over the first fuel cycle to 3.0 Hz with a corresponding decrease in the second mode resonant frequency. This second mode resonance merged with the CSB resonance resonance (6.7 Hz) to form what appears to be a single broad peak in the 5 to 7.5 Hz range, as shown in Fig. 1. The normalized root mean square (NRMS) of the neutron noise (at nominal full power conditions) in the 5- to 10-Hz frequency range increased by a factor of five from the beginning to the end of the first fuel cycle, as shown in Fig. 2. The NRMS was also found to depend inversely on soluble boron concentration changes associated with fuel burnup as shown in Fig. 3.

At the beginning of the second fuel cycle, the neutron noise amplitude in this same frequency range decreased, but only to a level somewhat higher than at the beginning of the first cycle (Figs. 2-3), and resonances could be distinguished only at 3.0 and 7.0 Hz (as shown in Fig. 1). In all measurements the phase and coherence relationships remained approximately constant, indicating that no significant change in CSB vibration direction occurred and that no incoherent noise sources (such as instrumentation noise) contributed to the PSD or CPSD increases.

The automated data acquisition system was removed on March 24, 1983; however, an analog recording of the neutron noise on August 5, 1983, showed the NRMS in the 5- to 10-Hz frequency range to be approximately 1.1×10^{-3} at a soluble boron concentration of 410 ppm.

Interpretation of Results and Conclusion

The neutron noise increases in the 5- to 10-Hz frequency range are interpreted as resulting from two primary mechanisms: excitation of the fuel assembly second mode of vibration due to CSB motion, and enhanced fuel assembly vibration-induced neutronic perturbations due to boron concentration changes and fuel burnup effects. The neutron noise increases observed in the 5- to 10-Hz range follow similar behavior observed in the 2- to 4-Hz range (dominated by the fuel assembly fundamental mode)[7] and at frequencies below 1 Hz.[8] There is no indication of loss of axial preload on the CSB, or restraint of movement by the lower internals guide lugs due to excessive CSB motion.

These results suggest that neutron noise measurements performed infrequently may not provide adequate surveillance of the CSB because it may be difficult to separate noise amplitude changes due solely to CSB motion from changes caused by fuel motion and burnup. Noise signatures should therefore be obtained at periodic intervals during each fuel cycle. The contribution of fuel assembly vibrations to neutron noise also implies that changes in fuel loading or fuel design are likely to change the behavior of these signatures significantly over a fuel cycle.

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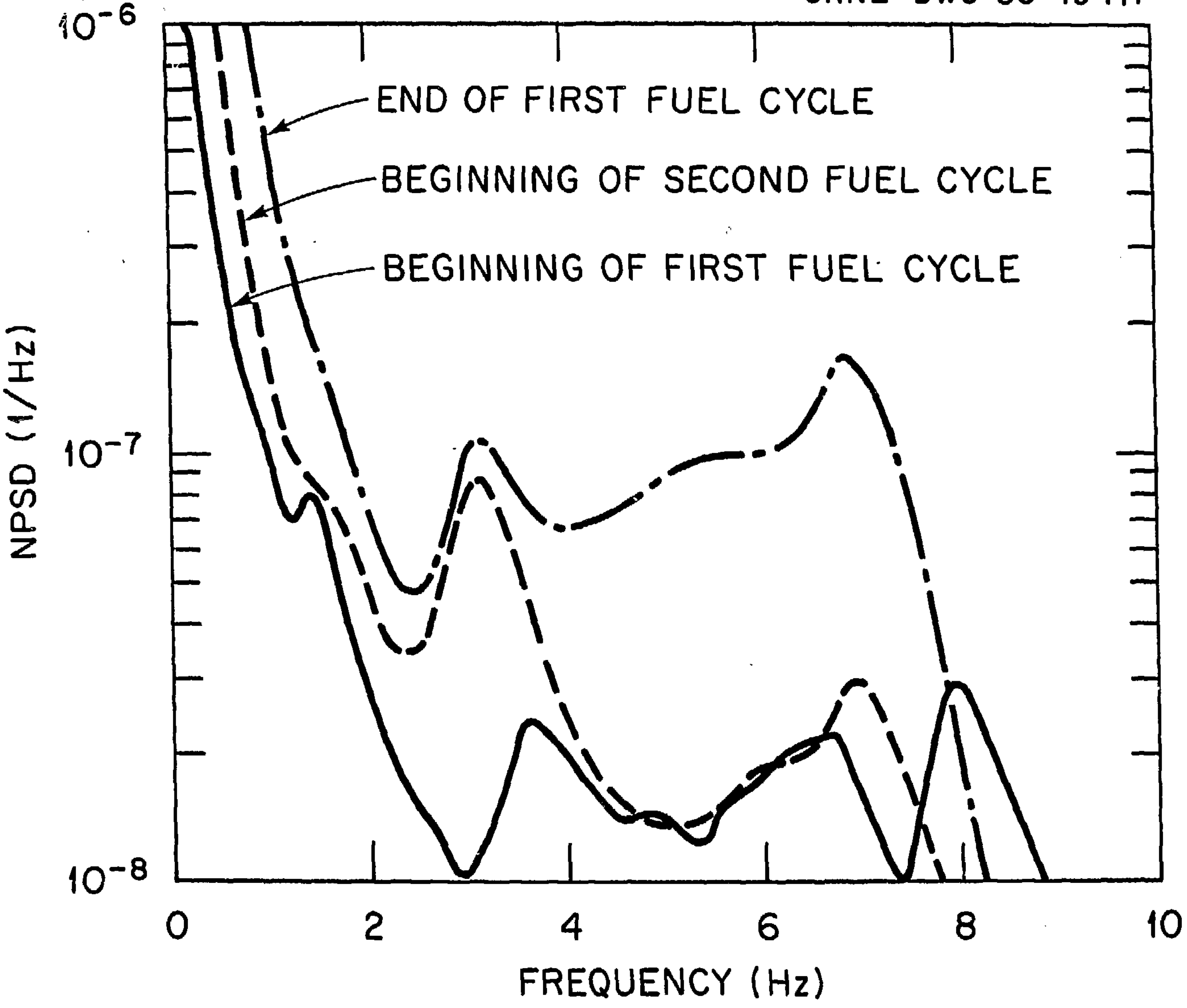

Fig. 1. Typical ex-core neutron detector power spectral density normalized to the mean reaction rate (NPSD) at Sequoyah-1.

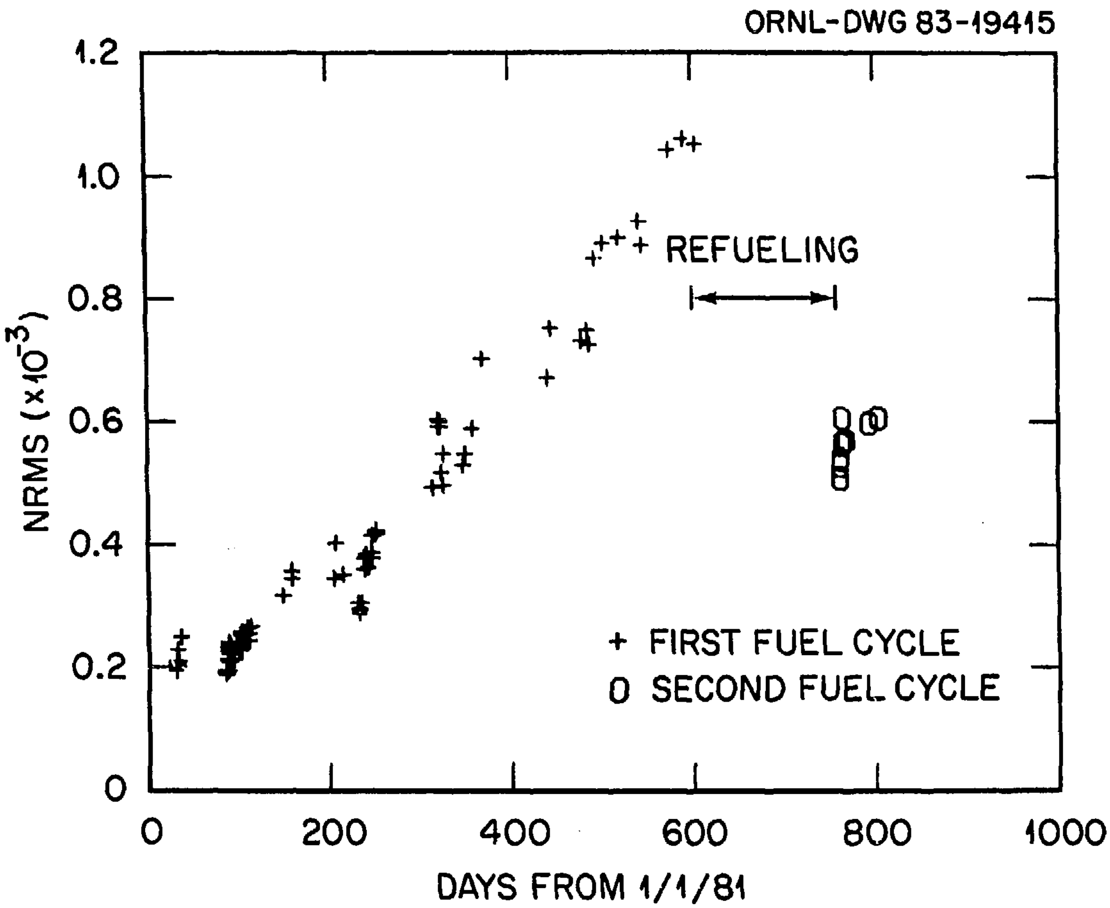

Fig. 2. Typical ex-core detector root mean square normalized to the mean reaction rate (NRMS) over the bandwidth 5 to 10 Hz at Sequoyah-1 versus number of days after 1/1/81.

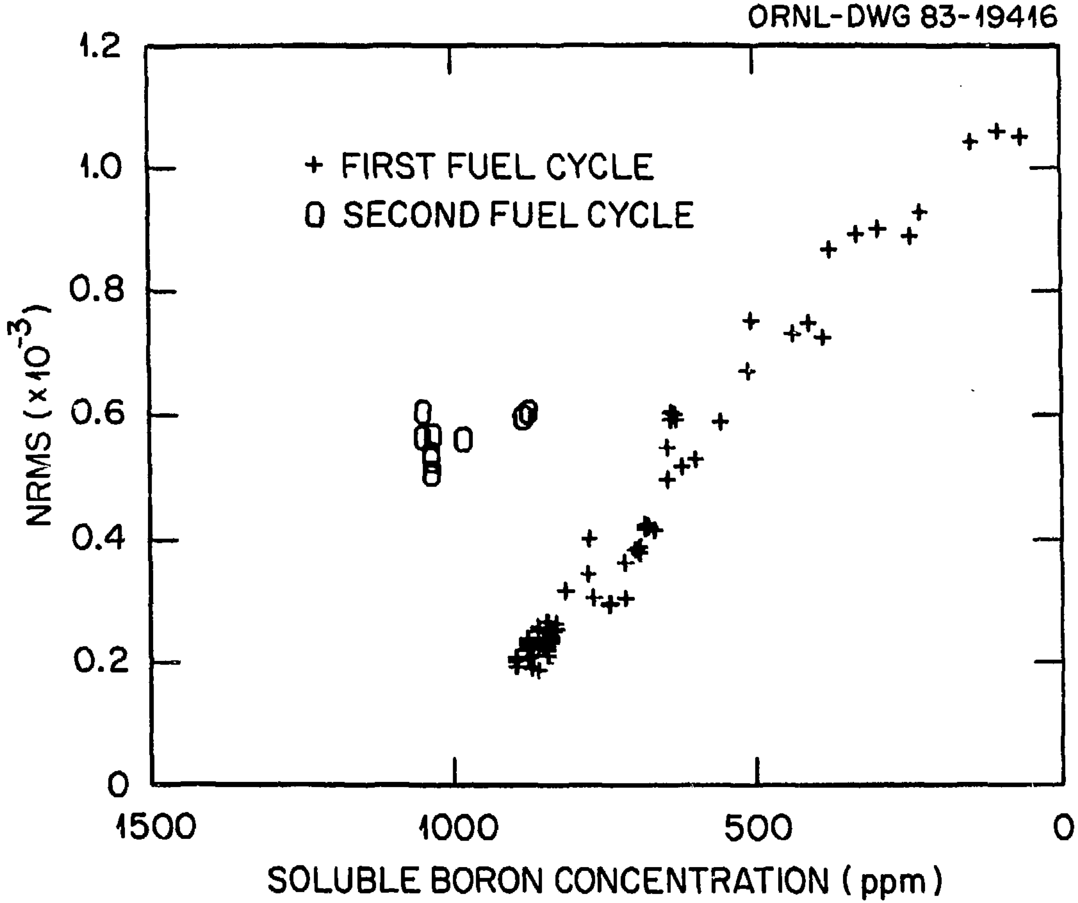

Fig. 3. Typical ex-core detector NRMS over 5 to 10 Hz at Sequoyah-1 versus soluble boron concentration.