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MONTE CARLO ANALYSIS OF THE VARIATION BETWEEN AXIAL POWER DISTRIBUTION AND DETECTOR RESPONSE (U)

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Monte Carlo Analysis of the Variation Between Axial Power Distribution and Detector Response (U)

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This analysis investigated the difference between axial power distribution and detector response for the cores operated at the Savannah River Site (SRS). This study supported the axial power shape uncertainty analysis for reactor power limit calculations.

The Savannah River reactors are moderated and cooled by D_2O and typically operate with approximately 450 cylindrical fuel assemblies that are arranged on a hexagonal lattice. The radial power distribution is extensively monitored by thermocouples and pressure taps at all assembly exits. Relative power distributions along the assemblies axial length are monitored by nine vertical Axial Power Monitor (APM) rods distributed throughout the radial plane. The APM rods monitor relative rather than absolute axial power because the assembly exit instrumentation provides the integral assembly power monitoring. Each APM rod has seven thermometers that respond to gamma heating of cylindrical aluminum detectors that are 2.7 cm tall and 0.635 cm in diameter. These sensors are located 0, ±76, ±107, and ±152 cm from the core midplane.

The MCNP code[1] was used for this analysis in order to properly account for the 3-dimensional effects of the variation in the axial power profiles within the radial plane. In addition, modeling the power distribution and the detector response required a coupled neutron - photon transport calculation.

To model the SRS core, an infinite lattice was created in the MCNP input. Supercells[2] were constructed containing six fuel assemblies and a septifoil assembly where control rods are inserted. APM rods were modeled in interstitial positions between three fuel assemblies. The supercell was repeated to a radius of ~ 15 m to model an infinite lattice. A concern that results might be biased by increasing the ratio of APM to fuel rods in the model over the actual core was investigated in preliminary calculations. This analysis revealed that modeling one APM rod in each supercell had essentially no impact in perturbing the power or photon distributions.

The axial power distribution was obtained from tallies of fission energy deposition taken at 20 axial layers. These tallies were taken over every assembly so that radial variation in the axial power profiles was averaged. APM detector response was obtained from photon energy deposition tallies over the detector volume.

The MCNP code was used in the criticality calculation mode. The fission source distribution was obtained by starting a single particle and iterating until the source distribution was fully developed. To assure that all fissile material regions were being sampled, the fission source development was verified by plotting the axial power distribution after intervals of several hundred thousand source particles.

Because the small physical size of the APM detectors created special difficulties in calculating the APM detector response, several variance reduction techniques were employed to reduce the statistical error in the photon tallies. One technique was to increase the APM detector volumes by a factor of about 20. Checks were made to assure that the particle distributions were not perturbed.

Weight splitting was applied to bias photons tracked to regions near detectors to give those photons higher importance. Weight splitting was implemented by modeling two concentric "ghost cylinders" in the D_2O surrounding the APMs. Photons entering the outer "ghost cylinder" were split into two particles each with half the original weight. Photons entering the inner "ghost cylinder" again underwent similar weight splitting. This technique increased the number of photons traversing the APM detectors, although the photons had lower weight.

Another variance reduction technique was to apply a weight threshold for photon production at the fission source. Photons below the threshold could be removed by Russian Roulette and their weight given to other particles. This technique reduces the computational expense of tracking low weight photons that do not contribute to reducing the tally variance.

Results from an MCNP calculation using 1.5 million source particle histories and approximately 30 Cray CPU hours are shown in Figure 1. Statistical uncertainties in the power distribution tallies are less than 1%. However, the uncertainties in the detector response tallies as indicated by the one standard deviation error bars range up to 5% relative error. From the figure we conclude that there is no discernible difference between the axial power distribution and detector response.

ACKNOWLEDGEMENT

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[1] J. Briesmeister, Ed.,"MCNP - A General Monte Carlo Code for Neutron and Photon Transport, Version 3A," LA-7396-M, Rev.2, Los Alamos National Lab. (1986).

[2] A.M. White,"MCNP Photon Transport Benchmarking Calculations Performed at SRP," *Trans. Am. Nucl. Soc.*, **59**, 345 (1989)

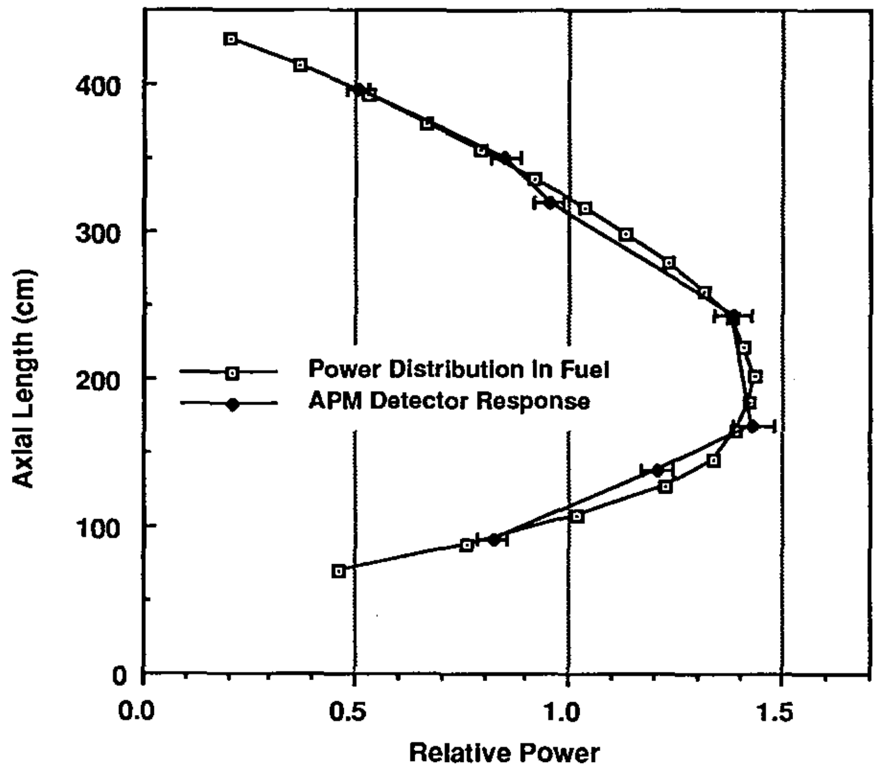

Figure 1. Axial Power Distribution and Detector Response