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SUMMARY

As part of the Advanced Fuel Recycle Program, critical mass measurements have been made of several lattices consisting of mixed oxide (PuO_2-UO_2) fuel pins in water.[1] In addition to providing a reliable technological basis for nuclear criticality control, these measurements are designed to provide benchmark data for validation of cross sections and calculational techniques used for mixed plutonium and uranium systems. In order to characterize some of the lattices more thoroughly, spatial fission rate distributions were measured using solid state track recorders (SSTR). These fission rate traverses cannot only be compared with calculated shapes, but since SSTR observations provide absolute fission rates, the data were also used as input to the multiple-foil unfolding code, SAND-II,[2] to derive adjusted neutron spectra. The extremely high sensitivity of the SSTR method affords in-situ dosimetry for critical mass measurements with negligible spatial and spectral perturbations.

The SSTR measurements were carried out using mica track recorders with isotopic fission deposits of ^{235}U, ^{238}U, ^{232}Th, and ^{237}Np. Fissions in the deposit create damage tracks in the mica, which can be counted under an optical microscope after suitable etching.[3] To measure spatial and isotopic fission

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rates simultaneously, it was necessary to adjust deposit thicknesses to obtain track densities as close as possible to the optimum range for manual scanning. The optimum range for high accuracy results varies from 10^4 tracks/cm^2 (to obtain statistical accuracy) up to 2×10^5 tracks/cm^2 (to avoid track pile-up). In order to obtain these densities, two types of deposits were used. Thin deposits provide low fission track densities with negligible fission fragment self absorption. The exact mass of such deposits must be determined and, if only part of the track recorder is to be counted, the deposit must be highly uniform. The second deposit type is one with a thickness greater than the range of all fission fragments. The sensitivity of these "asymptotic" foils is independent of the thickness and has been previously determined.[3,4]

Results from exposures at the middle of the lattice are shown in Table I for two pitches. In these measurements, each SSTR was scanned by two independent observers. Each observer scanned roughly 10^3 tracks, so that the statistical precision of the measurements is slightly greater than 2%. Errors due to the uncertainty in the mass of the fission deposit as well as the error in the optical efficiency of mica must also be considered. In this manner, an overall error of roughly 3-5% (at the 1σ level) was attained for SSTR absolute fission rate observations in these critical facility studies.

The measured fission rates were input to the SAND-II code together with a starting spectrum[1] calculated with the KENO[5] Monte Carlo code. The SAND-II code produced an adjusted calculated spectral shape which agreed with the measured data. Table I presents these SAND-II results for the thermal flux, flux of neutrons with energy greater than 0.1 and 1 MeV, total flux, and the mean neutron energy. A detailed error analysis was not made, but on the basis of similar analyses, uncertainties in these spectral values are estimated to be 10-15% (1σ).

The extent of modifications in the calculated spectra may be inferred by a comparison of measured and calculated ^{235}U (n,f) to ^{238}U (n,f) ratios. For the 0.77 cm pitch lattice this ratio was measured to be 107 as compared with the calculated (KENO) value of 119, an 11% difference. For the 1.90 cm pitch these were 1140 measured and 1236 calculated, an 8% difference. At other lattice positions, comparable differences were observed. As indicated by this one spectral index, therefore, the KENO calculations produce a reasonable approximation to the neutron spectrum. However, improvements in flux-spectrum values can be obtained from SAND-II, which may then be used for comparisons with lattice calculations or in perturbation calculations to derive effects of poison or geometry changes.

The results of this program to date have shown that accurate SSTR measurements of fission rates can be made in critical mass facilities at very low exposure levels. Such measurements when combined with the multiple foil technique have great potential for use as additional benchmark data for improvement and validation of calculational techniques.

Table I

Mid-Lattice Fission Rates and Group Neutron Fluxes

	Irradiation CS2	Irradiation CS6
Lattice Pitch	0.77 cm	1.90 cm
Relative Fission Rates: (fissions/atom-sec)		
^{235}U (n,f)	1.28×10^{-15}	2.28×10^{-15}
^{238}U (n,f)	1.19×10^{-17}	2.00×10^{-18}
^{232}Th (n,f)	3.60×10^{-18}	4.00×10^{-19}
^{237}Np (n,f)	8.52×10^{-17}	9.50×10^{-18}
Relative Flux (n/cm^2-sec)		
Thermal	1.85×10^{6}	4.31×10^{6}
E> 0.1 MeV	9.04×10^{7}	9.32×10^{6}
E> 1 MeV	3.48×10^{7}	4.48×10^{6}
Total	1.25×10^{8}	1.92×10^{7}
Average Energy (MeV)	0.92	0.70

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