Measured Delayed Neutron Spectra from the Fission of U-235 and Np-237,

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Texas A&M University, in collaboration with Oak Ridge National Laboratory and the Japan Atomic Energy Research Institute, have been actively studying the delayed neutron emission characteristics of the higher actinide isotopes for several years.[1-3] Recently, a proton recoil detector system was designed, built, and characterized for use in measuring delayed neutron energy spectra following neutron induced fission. The system has been used to measure aggregate delayed neutron energy spectra from neutron induced fission of U-235 and Np-237. These spectra have also been compared to that calculated using individual precursor P_n values, yields, and spectra from the ENDF/B-VI file.

A proton recoil detector array consisting of three LND Model 28305 high-pressure proton recoil detectors has been constructed at the Texas A&M University Nuclear Science Center. The array was characterized using several neutron and gamma-ray sources to check for efficiency, gamma-ray response, and reliability of the unfolding techniques. Resultant measured proton recoil distributions were unfolded using a modified version of the spectrum unfolding code PSNS (the new code was renamed SAC). SAC used response functions calculated using MCNP 4A. This feature allowed the inclusion of several inches of lead between the detector and the source to decrease the detector's sensitivity to gamma-rays, while appropriately accounting for the effect on the transmitted neutron spectrum.

Following proper calibration of the array, highly-purified sources of U-235 were irradiated in the Nuclear Science Center Reactor (NSCR) at a power of 1 MW for 200

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seconds. The samples were transferred to the detector array using a high-speed pneumatic system. The transfer time from core-to-detector was measured using photosensors and was found to be 0.57 seconds. The delayed neutron spectrum was then acquired for up to 600 seconds. The resultant spectra were then unfolded using the SAC unfolding code.

A similar technique was used to measure the delayed neutron spectra following a 200 second irradiation of a highly-purified sample of Np-237; however, due to the lower fission rate in the Np-237 sample, multiple irradiations were required to generate sufficient statistics for unfolding. Within a period of 4 hours, two Np-237 samples were irradiated up to eight times each. The counts from each sample were added together to generate a composite spectrum.

Figures 1 and 2 contain plots of the aggregate delayed neutron spectra from neutron induced fission of U-235 and Np-237, respectively. The figures also show the results from a summation calculation involving the 18 most predominant precursors using P_n values, yields, and individual precursor spectra from ENDF/B-VI. The uncertainty on the measured data is generally within 5%. As can be seen, the measured and calculated spectra show reasonable agreement even though the summation calculation included only 18 of the 271 identified precursors (~87% of the total delayed neutrons emitted). It is expected that better agreement will be found when more precursors are added to this calculation. Because this measurement was simply an aggregate spectrum measurement, it is difficult to compare the result to the few previous measurements. Experiments to measure time-dependent spectra are going to be performed in the future which will allow comparison to other results.

1. W. S. CHARLTON, T. A. PARISH, S. RAMAN, N. SHINOHARA, and M. ANDOH, *Proc. Int. Conf. on the Phys. of Reactors*, Mito, Japan, Sept. 16-20, 1996, p. F-11 (1996).

2. W. S. CHARLTON, T. A. PARISH, S. RAMAN, N. SHINOHARA, and M. ANDOH, *Proc. Int. Conf. on Nucl. Data for Sci. and Tech.*, Trieste, Italy, May 19-24, 1997, p. 491 (1997).

3. H. H. SALEH, T. A. PARISH, W. H. MILLER, H. OIGAWA, and S. RAMAN, *Nucl. Instr. and Methods in Phys. Res. B*, **103**, 393-400 (1995).

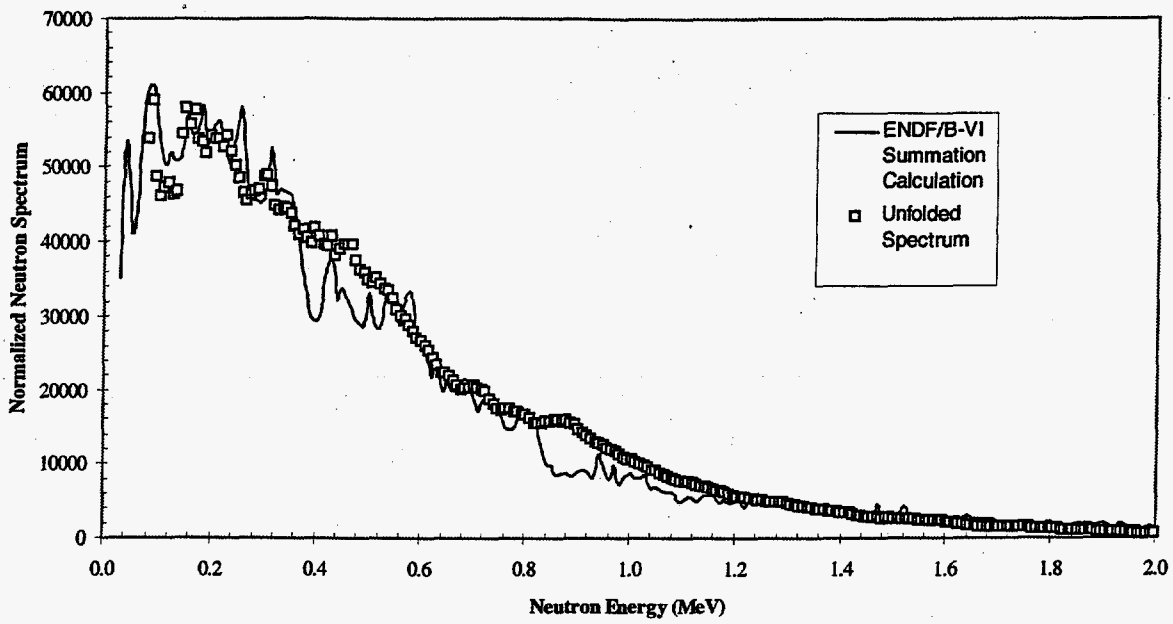

Fig. 1. Measured and calculated aggregate delayed neutron emission spectra for U-235.

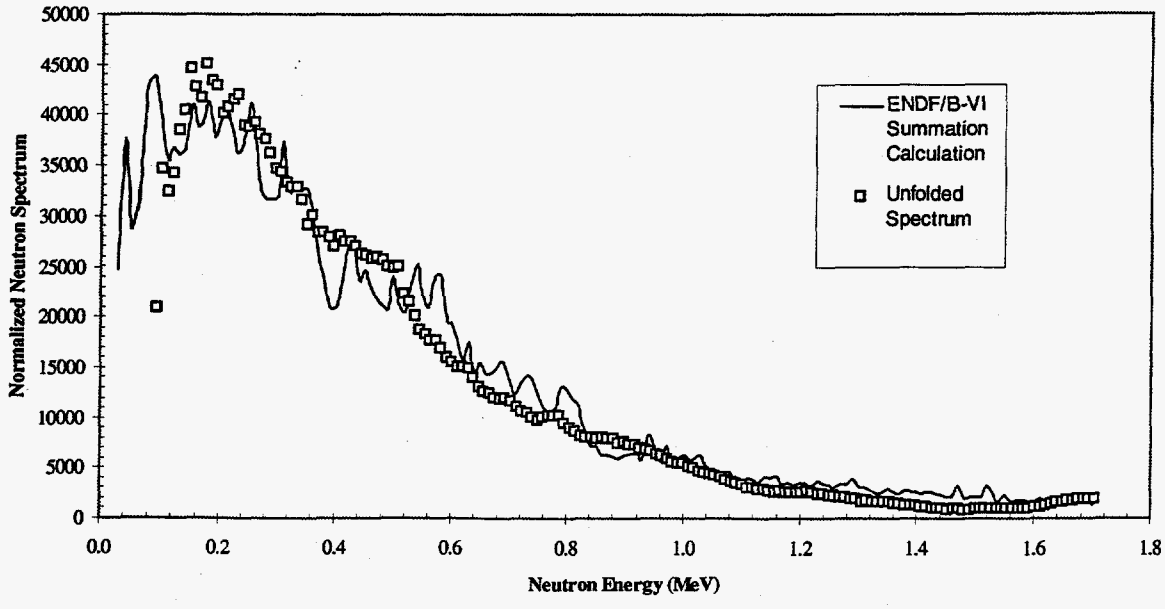

Fig. 2. Measured and calculated aggregate delayed neutron emission spectra for Np-237.