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TITLE: APPLICATION OF EVALUATED FISSION-PRODUCT DELAYED-NEUTRON PRECURSOR DATA IN REACTOR KINETICS CALCULATIONS

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APPLICATION OF EVALUATED FISSION-PRODUCT DELAYED-NEUTRON PRECURSOR DATA IN REACTOR KINETICS CALCULATIONS

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Astract Evaluated fission-product yield and decay data have been used to describe 105 delayed neutron precursors explicitly in point reactor kinetics calculations. Results calculated for ^{235}U thermal fission show that rod-drop reactivity values obtained from kinetics calculations with 6-group precursor data are considerably higher than those calculated with explicit delayed-neutron precursor data. The calculated kinetics associated with positive reactivity steps are significantly different.

INTRODUCTION

The temporal production of β^-,n delayed neutrons following fission have routinely been described using six precursor groups. These groups originated as 6-term, 12-parameter fits to experimentally measured count rates following fission-pulse and saturation-irradiation experiments with critical assemblies.[1,2] Use of the 6-group delayed-neutron representation in reactor kinetics calculations has become an industry standard.

Six-group data, describing the aggregate temporal delayed-neutron behavior, have been progressively reevaluated[3] for versions of ENDF/B.[4] Also measurements, nuclear model code calculations, and evaluation efforts continue to expand the data describing the production and decay of the individual fission-product delayed-neutron precursor nuclides. The fission-product decay data and fission yields of ENDF/B-V[4] and the updated precursor decay data of England et al.[5] form one consistent reference set of data with which a variety of delayed-neutron properties have been calculated.

This data set includes the identity, decay constant, neutron branching (P_n) value, detailed neutron emission spectrum, and fission yield of 105 delayed neutron precursors. Each of these are yielded directly in fission; all but one are also produced by the decay of one or more parent fission-product nuclides. The description of the temporal activity and delayed-neutron production rate of each of the 105 precursors requires the description of the temporal activity of 121 additional parent radionuclides.

DELAYED-NEUTRON PRODUCTION RATE CALCULATIONS

Modifications were made to AIREK-3[6] point reactor kinetics code to solve the differential equations describing the production and decay of each of the radionuclides. Code input was divided into problem-dependent, nuclide-decay,and fission-yield data files. The modified code AIREK-10, which calculates precursor inventory and nuetron density (or power) at specified times following a reactivity insertion, was validated for pulse and saturation calculations by comparison of delayed-neutron production rates calculated with CINDER-10[7], producing essentially identical results for all cooling times calculated ($\lesssim$500s). Similar agreement was observed between AIREK-10 calculated neutron densities (power) and analytic solutions obtained for step reactivities of +\$0.50, using a library of 7 fictitious precursors with complex couplings, and of -\$3.00, using the library of all 226 radionuclides.

AIREK-10 226-nuclide and 6-group calculations were made of delayed-neutron production rates following a ^{235}U thermal fission pulse, as shown in Fig. 1. The 6-group data sets were taken from Keepin, et al. [1,2], ENDF/B-V[4], and from England, et al.;[5] this last 6-group set sorts the 105 individual precursor contributions by half-life into the 6 temporal groups, ignoring the effects of parent nuclides. The comparison of production rates calculated with each of the 6-group sets to that calculated with 226 nuclides, given in Fig. 2, shows that all of the 6-group functions predict a lower delayed neutron production rate for the first 2-3 s, after which the production rate is calculated to be higher. (The total number of delayed neutrons per fission $\bar{\nu}_d$ is the same in all calculations.)

POINT REACTOR KINETICS CALCULATIONS

Calculations of relative neutron density, or power, were made with AIREK-10 following +\$0.50 and -\$1.00 reactivity steps, using the ENDF/B-V 6-group and 226-nuclide ^{235}U thermal-fission libraries. These results for the first 20 s following the reactivity steps, given in Fig. 3, show fair agreement for negative \$1 reactivity steps but significantly higher neutron density (power) increases calculated with explicit nuclide data for positive 50¢ reactivity steps. Figure 4, showing typical reactor rod-drop calibration curves calculated for ^{235}U thermal fission using the same two libraries, indicate that a reactivity measurement evaluated at \$3.00 with explicit nuclide data would be evaluated at \$3.23 with the ENDF/B-V 6-group functions.

CONCLUSIONS

Reactivity evaluations made for ^{235}U thermal fission with 6-group functions are significantly higher than those made with explicit nuclide data. Explicit nuclide reactivity calculations could seriously impact design and operating-reactor reactivity evaluations for all fuels.

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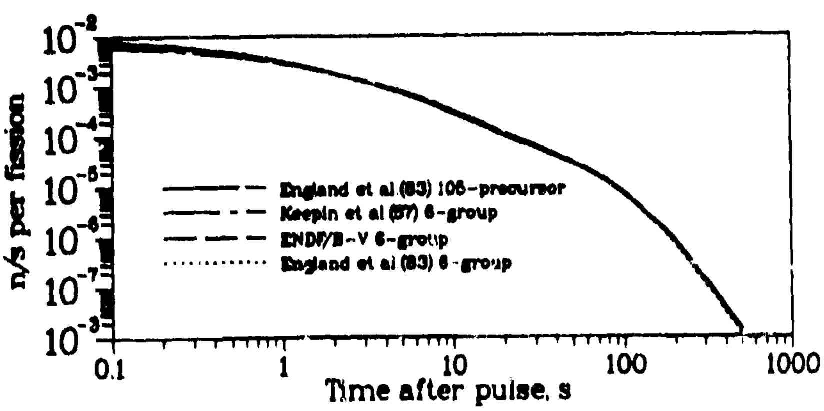

FIGURE 1 Calculated delayed neutron production rates following a ^{235}U thermal fission pulse.

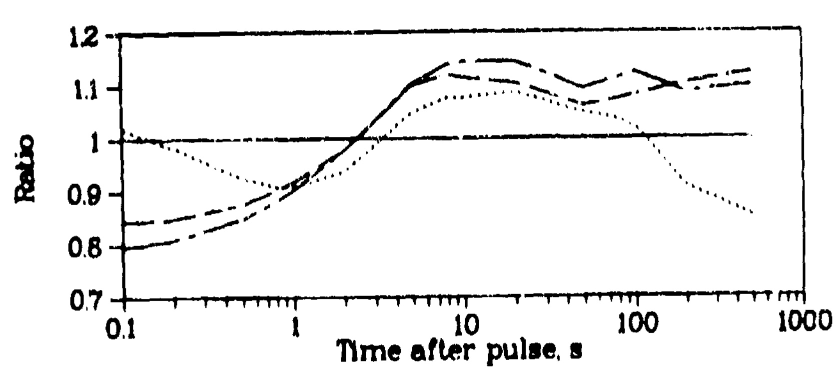

FIGURE 2 Ratio of 6-group to 105-precursor calculated delayed neutron production rates following a ^{235}U thermal fission pulse.

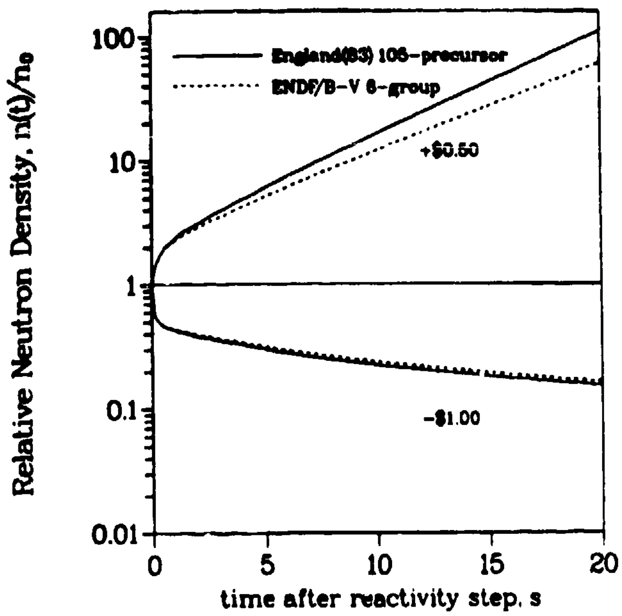

FIGURE 3 Comparison of 105-precursor and ENDF/B-V 6-group calculated neutron density following +$0.50 and -$1.00 step reactivity inputs, ^{235}U thermal fission.

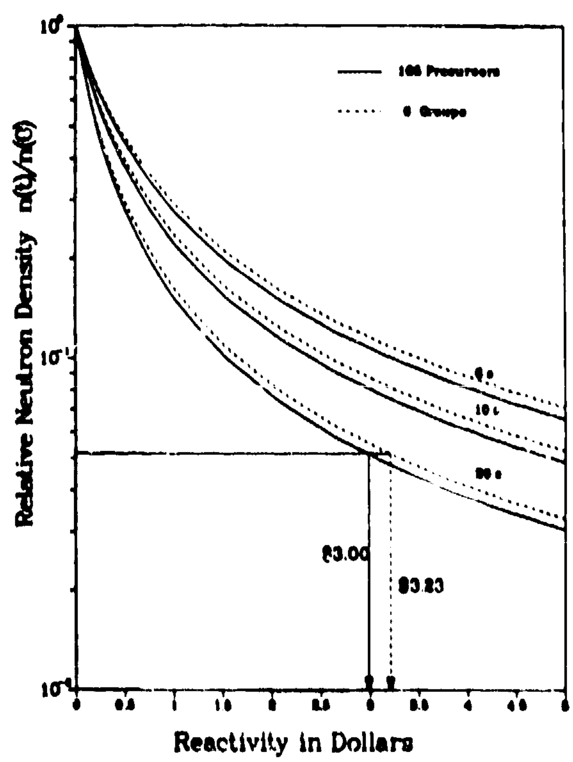

FIGURE 4 Rod calibration curves, ^{235}U thermal fission.