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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Abstract 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 235U 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 \( \beta^-\text{n} \) 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 (\( P \)) 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
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the decay of one or more parent fission-product nuclides. The
description of the temporal activity and delayed-neutron produc-
tion 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 ATREK-3E point reactor kinetics code
to solve the differential equations describing the production and
decay of each of the radionuclides. Code input was divid.d into
problem-dependent, nuclide-decay, and fission-yield data files.
The modified code AIREK-10, which calculates precursor inventory
and neutron 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-107, producing essentially identical re-
sults for all cooling times calculated (2500s). Similar agree-
ment 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 radionu-
clides.

AIREK-10 226-nuclide and 6-group calculations were made of
delayed-neutron production rates following a 235U thermal fission
pulse, as shown in Fig. 1. The 6-group data sets were taken from
Keepin, et al. 1,2, ENDF/B-V4, 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 nu-
clides, 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 $d$ 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 235U thermal-fission libra-
ries. These results for the first 20 s following the reactivity
steps, given in Fig. 3, show fair agreement for negative $1 re-
activity steps but significantly higher neutron density (power)
increases calculated with explicit nuclide data for positive 50C
reactivity steps. Figure 4, showing typical reactor rod-drop
calibration curves calculated for 235U thermal fission using the
same two libraries, indicate that a reactivity measurement eval-
uated at $3.00 with explicit nuclide data would be evaluated at
$3.23 with the ENDF/B-V 6-group functions.
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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.

REFERENCES


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, $^{235}\text{U}$ thermal fission.

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