LA-UR-98-303

LA-UR--98-303

Title:

A Few-Group Delayed Neutron Model Based on a Consistent Set of Decay Constants

CONF-980606--

RECEIVED
JUL 01 1998
OSTI

Author(s):

Joann M. Campbell
Gregory D. Spriggs

Submitted to:

American Nuclear Society
1998 Summer Meeting
June 7-11, 1998
Nashville, TN

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

January 22, 1998

Los Alamos
NATIONAL LABORATORY

A Few-Group Delayed Neutron Model Based on a Consistent Set of Decay Constants

Joann M. Campbell and Gregory D. Spriggs
Los Alamos National Laboratory, P. O. Box 1663, MS D409, Los Alamos, NM 87545-0001

Delayed neutron parameters used in reactor dynamic calculations have traditionally been determined from a least-squares fit (LSF) of an aggregate decay curve of delayed neutrons emitted from a small sample of fissionable material irradiated by a strong neutron source, such as a reactor or a cyclotron. When performing the LSF, it has been customary to assume that the decay curve can be represented by the sum of exponentials (usually 5 or 6) in which both the abundances, a_i, and the decay constants, λ_i, of the exponentials are free parameters in the fit. As a consequence of allowing all parameters to be free in the LSF, the converged values of the abundances and decay constants usually differ from isotope to isotope as well as varying as a function of incident neutron energy. Furthermore, because the LSF is merely a mathematical minimization of a chosen function to a given set of data, the decay constants obtained in this fashion will not necessarily converge to the decay constants of any of the 271 potential delayed neutron emitters. As explained by Keepin,[1] the decay constants obtained during the LSF of the aggregate decay curve actually represent weighted averages based on the abundances and half-lives of the various precursors contributing to each group; therefore, small variations in the decay constants should be expected since the fission yields of the 271 precursors vary from isotope to isotope and with incident neutron energy and, because it is just a few-group model, one should not expect the decay constants to necessarily coincide with any particular precursor.

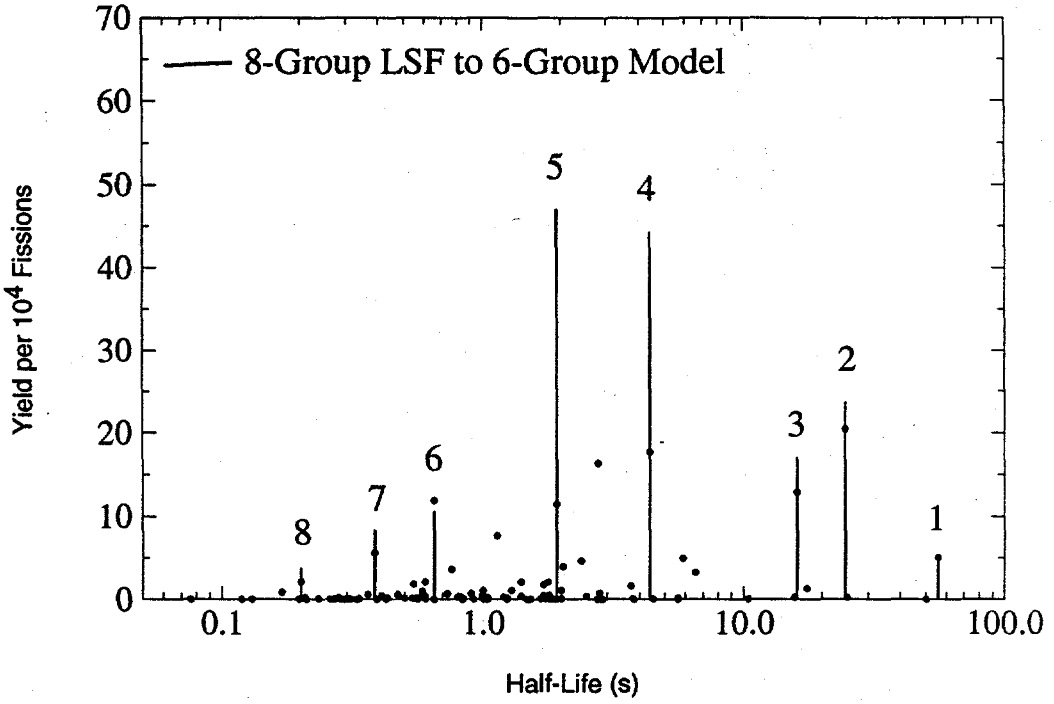
As shown by Gudkov et al.,[2] at least 82% of all delayed neutrons in most common fissioning systems are produced by the same eight precursors. Therefore, it seems logical that a reasonable alternative to the current few-group model is to increase the number of delayed neutron groups to at least eight so that variations in the effective decay constants become small enough that, for all intents and purposes, they can be treated as constants in the LSF. The aggregate decay curve can then be fit to determine the corresponding abundances that yield the same quality of fit. Hence, in principle, one can formulate a complete set of delayed neutron parameters for all fissionable isotopes and all incident neutron energies based on a consistent set of decay constants in which only the abundances vary. From a reactor dynamic standpoint, this sort of delayed neutron model would greatly simplify the dynamic model needed to accurately simulate the time-dependent behavior of reactor systems containing several fissionable isotopes.

The idea of generating a set of delayed neutron parameters based on a consistent set of decay constants was first attempted by Keepin[1] using a 6-group model, but was eventually abandoned because the quality of fit was not as good as the more general LSF. More recently, however, Spriggs[3] has shown that most few-group models (e.g., 5- or 6-group models) can be expanded into an equivalent 8-group model using fixed decay constants corresponding to known dominant precursors without significantly altering the quality of the fit, or the reactivity scale, or the predicted time-dependent behavior of a reactor system over a relatively large power range. This development has rekindled some new interest in the concept of having a delayed neutron model based on a consistent set of decay constants, and is now being studied by the international steering committee on delayed neutrons. As part of this international effort, the Los Alamos National Laboratory has been asked to (1) determine if there is a set of dominant precursors that are common to all fissionable isotopes and all incident neutron energies, (2) expand the existing experimentally-measured few-group models commonly used in the nuclear industry into their 8-group equivalent using a consistent set of decay constants corresponding to these dominant precursors, and (3) formulate new group spectra for the equivalent 8-group model.

In response to this request, LANL has calculated the theoretical delayed neutron yield for 14 different isotopes using three different incident neutron spectra (i.e., thermal, fast, and 14.1 MeV) using the current fission-yield and emission probability data found in ENDF-VI. An example of these results is shown in Fig. 1 in which the theoretical delayed neutron yields for the 271 precursors produced during thermal fission of ^{235}U are plotted against the half-lives of the precursors. By comparing the results for all 14 isotopes, a preliminary set of precursors has been identified that are dominant within the various half-life regimes of the delayed neutron precursors (see Table I). Also plotted on Fig. 1 are the group yields of the 8-group equivalent model of Keepin's 6-group model.[4] And finally, an example of the delayed neutron spectra for group 7 in the 8-group equivalent model is shown in Fig. 2. A final report summarizing all results is expected to be released for review by the international steering committee by the summer of 1998.

Table I. Half-Lives for 8-Group Model

Group	Precursor	Half-life (s)
1	Br-87	55.6
2	I-137	24.5
3	Br-88	16.3
4	Br-89	4.35
5	Br-90	1.91
6	Y-98	0.548
7	Rb-95	0.378
8	Rb-96	0.203



Fig, 1. Theoretical delayed neutron yield from individual precursors produced during thermal fission of ^{235}U vs. half-life of the precursor. The solid vertical lines represent the 8-group equivalent of Keepin's 6-group model.

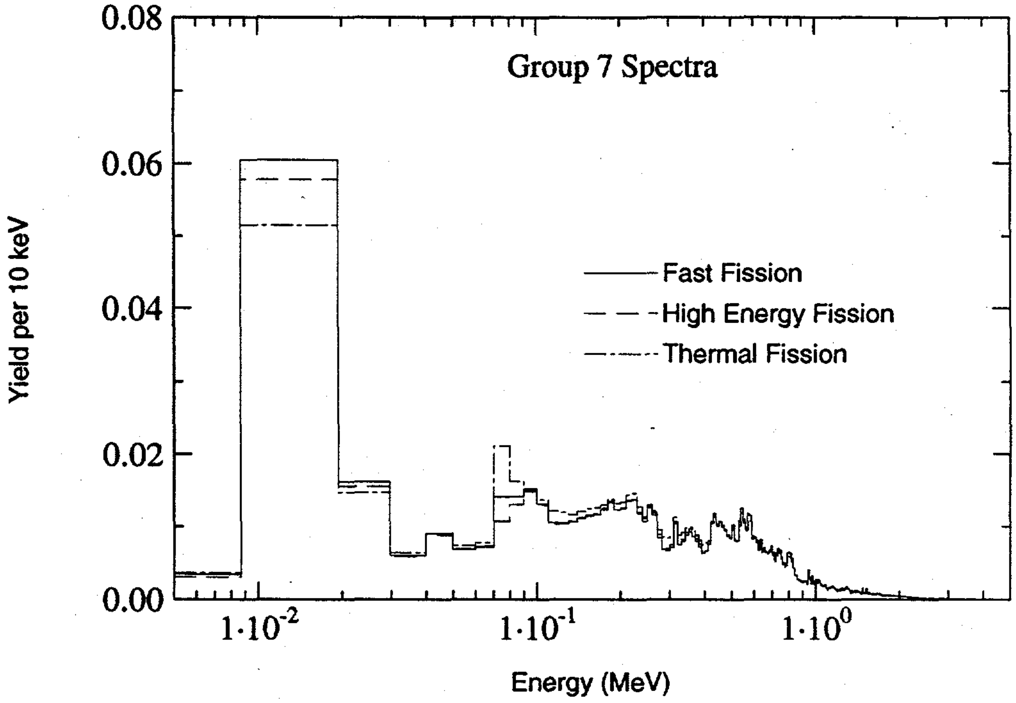


Fig. 2. An example of the delayed neutron spectra for group 7 of the 8-group equivalent of Keepin's 6-group model.

REFERENCES

1. G. R. KEEPIN, Physics of Nuclear Kinetics, Addison-Wesley Pub. Co., 1965.
2. A. N. GUDKOV, S. V. KRIVASHEYEV, A. B. KOLDOBSKI, V. V. KOVALENKO, E. Yu. BOBKOV, and V. M. GIVUM, "Yields of Delayed Neutron Precursors in the Fission of Actinides," *Radiochimica Acta*, **57**, 69 (1992).
3. G. D. SPRIGGS, "Overview of In-Pile Measurements of Delayed Neutron Parameters," oral presentation at *International Colloquy on Delayed Neutrons*, Obninsk, Russia (April 7-9, 1997).
4. G. R. KEEPIN, T. F. WIMETT, and R. K. ZEIGLER, "Delayed Neutrons from Fissionable Isotopes of Uranium, Plutonium, and Thorium," *Physical Review*, **107**, No. 4, 1044 (1957).