

LA-UR- 97-2211

Approved for public release;
distribution is unlimited.

CONF-971125-

Title:

Further Investigation of Spectral
Temperature Feedbacks

Author(s):

Drew E. Kornreich
TSA-7, MS F609

Submitted to:

Transactions of the American Nuclear
Society for the Nov. 1997 Meeting

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

19980330 017

MASTER

Los Alamos
NATIONAL LABORATORY

DTIC QUALITY INSPECTED 3

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the U.S. Department of Energy under contract W-7405-ENG-36. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. The Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, make any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

FURTHER INVESTIGATION OF SPECTRAL TEMPERATURE FEEDBACKS

Drew E. Kornreich
TSA-7, MS F609
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

INTRODUCTION

A renewed interest in the phenomenon of possible positive temperature reactivity feedback coefficients in dilute fissile solutions has occurred over the past ten years.^{1,2} Examination of the geologic disposal of fissile materials often includes the study of the possibility of autocatalytic reactions (those with positive feedback coefficients of reactivity) as the result of the different effective multiplications for fissile material in wet and dry ground. However, another postulated autocatalytic reaction occurs for dilute solutions of plutonium. Such solutions have been seen, through calculations, to have positive temperature reactivity feedback coefficients.^{3,4} Including a non- $1/v$ neutron poison like gadolinium enhances the effect (although larger feedback coefficients are unimportant if criticality cannot be achieved).

This paper serves two purposes: (1) to introduce some new calculations of the temperature coefficients for uranium solutions, and (2) to examine some simplified calculations based on earlier work.⁴ Uranium solutions, while never having positive temperature coefficients, show trends in the feedback coefficient as a function of solution concentration that are similar to those seen for plutonium solutions. For both the plutonium and uranium solutions, the feedback coefficient experiences a local minimum near the over/under moderation transition point. The earlier work on the simplified calculations is expanded to include better treatment of cross sections and to include strict numerical integration techniques.

BACKGROUND

The temperature coefficient of reactivity feedback has essentially two components, the feedback from density changes as a function of temperature and the feedback from changes in the thermal neutron spectrum that result from temperature changes. The latter effect is the result of the energy-dependent cross sections for neutron interactions; as the thermal neutron spectrum is altered by changes in the macroscopic temperature of the system, different nuclear interaction cross sections are encountered by the neutrons. This causes increases or decreases in the fission and parasitic absorption rates, which directly translates to a reactivity feedback mechanism.

The change in reactivity, R , as a function of temperature is given formally by

$$\frac{dR}{dT} = \frac{\partial R}{\partial \rho} \frac{d\rho}{dT} + \frac{\partial R}{\partial T_n} \frac{dT_n}{dT} . \quad (1)$$

The first term in Eq. (1) describes the (geometry-dependent) reactivity feedback as a result of density changes as a function of temperature, and the second term in Eq. (1) describes the (material-dependent) reactivity feedback that results from neutron spectral shifts as a function of temperature. It is this second term that is of interest in this paper. If the system contains large amounts of hydrogen, then the neutron spectrum will be very thermalized. If the thermal flux can be approximated by a Maxwellian distribution, then the thermal neutron flux is given by

$$\phi_M(E, T_n) = C \frac{E}{T_n^{3/2}} e^{-E/kT_n} , \quad (2)$$

where C is a constant and k is Boltzmann's constant. Using the standard four factor formula definitions for a thermal system ($\varepsilon \approx 1, p \approx 1$), the reactivity, which is defined as usual as $(k-1)/k$, is

$$R = 1 - \frac{1}{k} = 1 - \frac{\int_0^{E_T} dE \phi_M(E, T_n) \Sigma_a(E)}{\int_0^{E_T} dE \phi_M(E, T_n) v \Sigma_f(E)} , \quad (3)$$

where E_T is the upper limit of the thermal region (assumed to be 0.4 eV) and the usual definitions of the macroscopic cross sections are used. Eq. (3) clearly exhibits the temperature dependence of the reactivity. Differentiating Eq. (3) with respect to the neutron temperature yields the spectral temperature feedback coefficient as

$$\alpha = \frac{\partial R}{\partial T_n} \frac{\partial T}{\partial T} = \frac{1}{[k(T_n)]^2} \frac{dk(T_n)}{dT_n} = \frac{1}{T_n} \frac{I(\Sigma_a) I'(\nu \Sigma_f) - I(\nu \Sigma_f) I'(\Sigma_a)}{I(\Sigma_a)^2} \quad (4)$$

with

$$I(\Sigma) = \int_0^{E_T} dE \Sigma(E) E e^{-E/kT_n} , \quad (5a)$$

and

$$I'(\Sigma) = \int_0^{E_T} dE \Sigma(E) E e^{-E/kT_n} \left[\frac{E}{kT_n} - \frac{3}{2} \right] . \quad (5b)$$

Eqs. (4) and (5) allow for a simplified analysis that can be performed to estimate the spectral reactivity feedback coefficient in dilute solutions of fissile material.

RESULTS

A simple algorithm has been constructed to perform the calculations implied by Eqs. (4) and (5). The microscopic cross sections are fit to appropriately defined curves based on experimental data up to 0.4 eV (E_T). Integrals were evaluated using Romberg integration⁵ or iterative Gauss-Legendre quadrature, where successively larger quadrature orders are used until two or more calculated values of the integral are within a prescribed tolerance.

The spectral temperature coefficient is essentially a property of the material; however, the critical assemblies are of finite size. The effects of density changes in a finite geometry can be included in a total temperature coefficient calculation for a critical system by first estimating the radius of the critical system using standard one-group theory.⁶ This would yield a total temperature coefficient of reactivity.

Several calculations have been performed to determine the accuracy of the aforementioned treatment. First, the infinite-medium effective multiplication is easily determined using Eq. (3). A comparison of the simplified treatment discussed here to a detailed 69-group calculation using DANTSYS⁷ is shown in Figure 1. At small concentrations, the agreement is close, but as the concentration increases, results from the two methods diverge. The inability of the simplified model to treat the effects of over and undermoderation is the most likely explanation, and is readily visible when the infinite multiplication factors for the two models are compared. Also, the spectral temperature coefficient is not independent of the geometry, as the critical and infinite-medium 69-group calculations indicate.

REFERENCES

1. W. E. KASTENBERG, et al., "Considerations of Autocatalytic Criticality of Fissile Materials in Geologic Repositories," *Nuclear Technology*, **115**, 298 (1996).
2. C. D. BOWMAN, and F. VENNERI, "Underground Supercriticality from Plutonium and Other Fissile Material," *Science & Global Security*, **5**, 279 (1996).
3. D. E. KORNREICH, "Reactivity Feedback Mechanisms in Aqueous Fissile Solutions," *Nuclear Science and Engineering*, **115**, 50 (1993).
4. T. SUZAKI, Y. MIYOSHI, and H. HIROSS, "Evaluation of Temperature and Void Coefficients of Reactivity in Homogeneous Solutions Fuel Assemblies," International Seminar on Nuclear Criticality Safety, Tokyo, Japan (1987).
5. D. ZWILLINGER, *Handbook of Integration*, Boston: Jones and Bartlett Publishers, 1992.
6. J. R. LAMARSH, *Introduction to Nuclear Engineering*, Reading, Massachusetts: Addison-Wesley Publishing Company, 1983.
7. R. E. ALCOUFFE, R. S. BAKER, F. W. BRINKLEY, D. R. MARR, R. D. O'DELL, and W. F. WALTERS, "DANTSYS: A Diffusion Accelerated Neutral Particle Transport Code System," Los Alamos National Laboratory, LA-12969-M (1995).

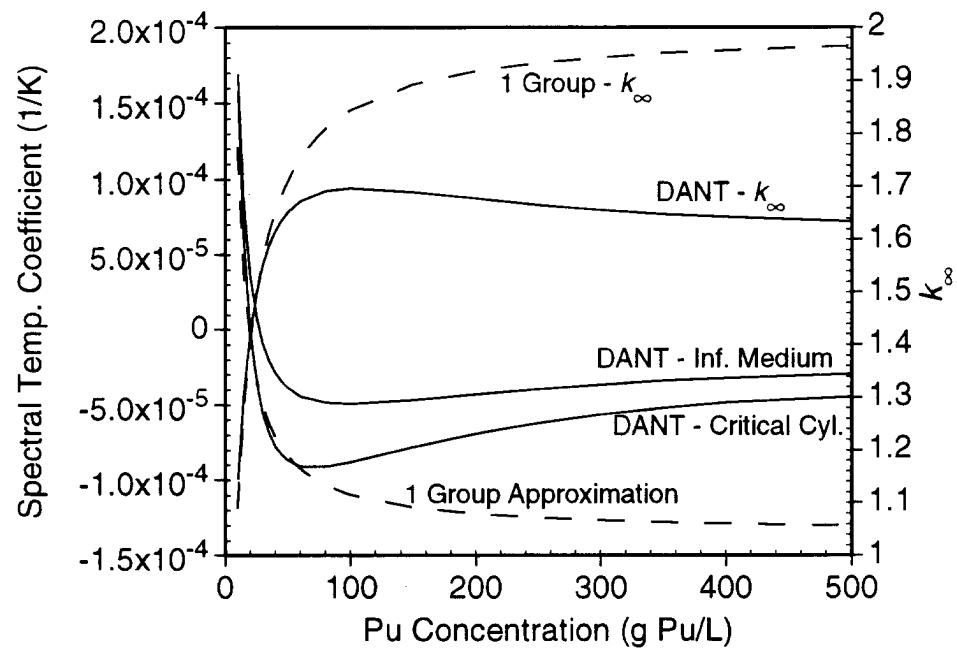


Fig. 1. The spectral temperature coefficient and multiplication factors for 69-group and 1-group models.

M97008622



Report Number (14) LA-UR-97-2211
CONF-971125

Publ. Date (11) 199708
Sponsor Code (18) DOE/DP, XF
UC Category (19) CLC-700, DOE/ER

DOE