Nuclear Science and Technology Division

Review of Plutonium Solution Biases

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Preliminary results of simultaneous analysis of plutonium metal and solution critical experiments and corresponding conclusions regarding calculational accuracy of simple safety applications will be provided in this paper.

A suite of the considered experiments was formed by a research group at the Institute of Physics and Power Engineering. The group had evaluated and provided a preliminary correlation matrix for the selected experiments and in some cases reevaluated experimental uncertainties. This preliminary information was used to examine computational biases and uncertainties.

Computational accuracies were determined for simple subcritical (k_{eff} = 0.97) systems that were represented by fully water-reflected, spherical-geometry steel tanks filled with plutonium solutions having varied concentrations. Tank diameters were determined for the k_{eff} = 0.97 condition. The materials considered are provided in Table 1.

Table 1. Descriptions of Simple Safety Applications

Reactor-grade plutonium (74 wt % Pu-239, 19 wt % Pu-240, 6 wt % Pu-241, 1 wt % Pu-242)								
Parameter \ Case	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6	Case-7	Case-8
H/Pu	16.89	29.81	99.54	298.7	597.6	993.4	1495	1991
H/(Pu-239+Pu-241)	21.09	37.23	124.3	373.1	746.5	1241	1867	2487
G_{Pu}, g/L	736.3	622.9	239.6	85.12	43.23	26.17	17.44	13.12
R_{sol}	22.78	18.78	16.57	16.26	17.99	21.38	27.58	38.08
k_{eff}	0.9677	0.9680	0.9678	0.9674	0.9677	0.9681	0.9686	0.9691
Weapon-grade plutonium (95 wt % Pu-239, 4.5 wt % Pu-240, 0.5 wt % Pu-241)								
Parameter \ Case	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6	Case-7	Case-8
H/Pu	16.89	29.81	99.54	298.7	597.6	993.4	1495	1991
H/(Pu-239+Pu-241)	17.68	31.21	104.2	312.7	625.7	1040	1565	2084
G_{Pu}, g/L	735.4	622.1	239.3	85.02	43.17	26.14	17.42	13.10
R_{sol}	18.75	15.07	13.64	13.86	15.34	17.84	21.85	27.27
k_{eff}	0.9672	0.9672	0.9672	0.9668	0.9673	0.9674	0.9681	0.9685

All critical experiment configurations were analyzed using the TSUNAMI-3D sequence (Monte Carlo method) of the SCALE5 code system. The k_{eff} values and their sensitivities to neutron data were calculated together. Each simple safety application configuration was calculated using the TSUNAMI-1D sequence (S_n-

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method) of the SCALE code system. The ENDF/B-V 238-energy-group neutron data library provided in the SCALE code system was used.

The Oak Ridge National Laboratory prototypical TSURFER code was used as a basic tool for the sensitivity and uncertainty analysis. In this code the General Linear Least-Squares Method is used. This code calculates a similarity parameter, c. It characterizes a degree of the similarity for two arbitrary (sub-) critical configurations. The analysis of the c parameter values for all experiment-application pairs showed that all selected experiments with plutonium solutions model the applications sufficiently (for most pairs $c > 0.8$). The experiments with plutonium metal were excluded from further consideration since their corresponding c values equaled ~0.5 or less.

The total χ^2 value per degree of freedom from the experimental dataset is 1.47. This relatively large total value indicates that there are some inconsistencies among the experimental or/and calculational values that should be understood. The scatter of the percent differences in the computed values minus the experimental critical values is shown in Figure 1.

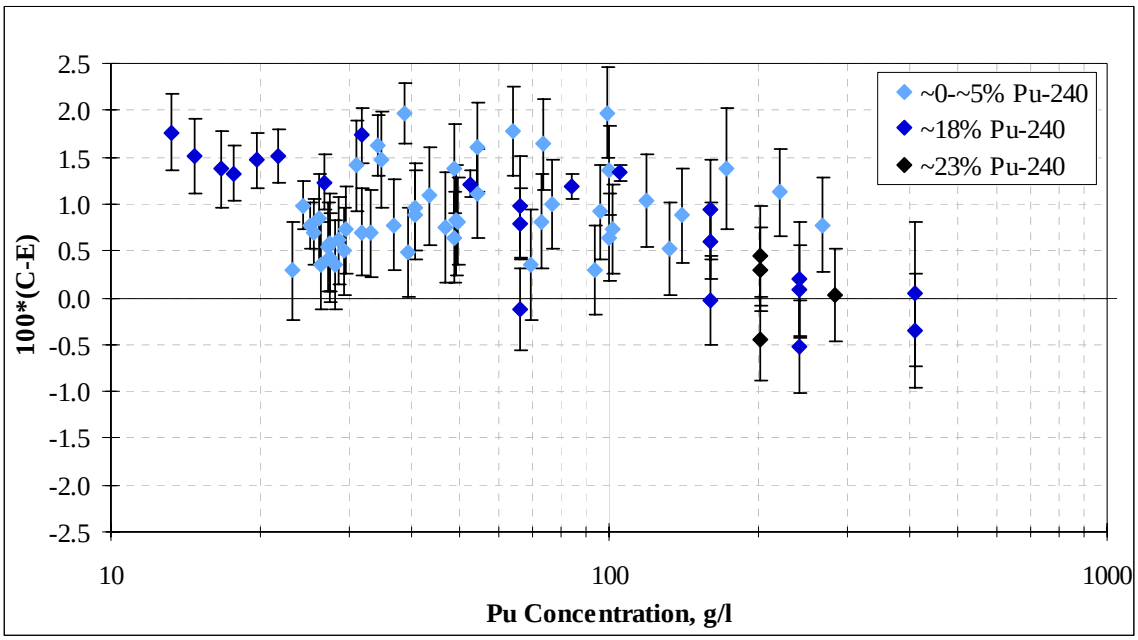

Figure 1. Differences between Computed Values and Experimental Critical Values

Use of TSURFER provides the opportunity to examine neutron-cross-section energy-reaction importances on the bias and uncertainty of calculations as influenced by both neutron-data and critical-experiment correlation coefficients. This paper will provide results and insights about (1) the variation of data biases, (2) the variation of uncertainties, (3) the potential reduction in computational biases from data improvements/evaluations, and (4) the seemingly anomalous results from using neutron-data and critical-experiment correlation coefficients.