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Investigations and Recommendations on the Use of Existing Experiments in Criticality Safety Analysis of Nuclear Fuel Cycle Facilities for Weapons-Grade Plutonium

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EXECUTIVE SUMMARY

Sensitivity and uncertainty (S/U) methodologies under development at Oak Ridge National Laboratory (ORNL) were applied to evaluate critical experiment applicability to a range of Mixed Oxide Fuel Fabrication Facility (MFFF) design systems. Duke, Cogema, Stone and Webster (DCS) provided ORNL with compositions and dimensions for critical systems used to establish preliminary mass limits for facility powder and fuel pellet handling areas. Data for seven distinct critical configurations were provided. Three of the design applications evaluated in this report are PuO_2 powder systems and four are mixed-oxide (MOX) powder systems.

Using traditional criticality analysis validation techniques, a number of benchmark quality critical experiments were identified by DCS as applicable to the seven design systems evaluated in this report. These experiments were identified by DCS in a preliminary criticality code validation document supplied to ORNL at the inception of this work. ORNL analyzed each of these experimental configurations, along with a wide range of additional plutonium, uranium, and mixed plutonium and uranium experiments using the sensitivity analysis sequence SEN3, which will be included in the next release of the SCALE[1] code system. This sensitivity data and cross-section uncertainty data were then processed with the S/U analysis code CANDE[2] to determine the correlation of each application to each experiment in the benchmarking set. The criterion for the applicability of an experiment for use in the criticality code validation of design systems is established by the value of the correlation coefficient, c_k, of 0.8 or higher. This criterion is based on the results of a previous study.[3] As stated in this previous study, the criterion of 0.8 is somewhat arbitrary and may be re-evaluated in future studies. For the current report, only the S/U-based correlation coefficient, c_k, is considered. Previous studies have demonstrated that the use of sensitivity-only based integral parameters, E_{sum}, may be inappropriate for systems containing plutonium due to the anti-correlation of certain components of the cross-section data.[4]

Of 318 benchmark experiments evaluated in this study, 91 were determined to satisfy the criteria used to define applicability to PuO_2 powder systems. For the MOX powder design systems evaluated, 67 of the 318 experiments were identified as applicable. Of the 46 experiments identified as applicable to PuO_2 powder systems by preliminary DCS work using traditional validation selection techniques, 38 were confirmed as applicable by S/U analysis. Similarly, all 14 experiments identified by DCS as applicable to MOX powder design systems were confirmed by S/U techniques to be applicable. One MOX powder design system appeared to be outside the area of applicability of the selected benchmark experiments based on traditional validation techniques. However, the S/U methods demonstrated that 54 of the 318 benchmark experiments exceeded the applicability criterion for this design system.

Other insights provided by the S/U studies performed in this work include the inability to cover the entire area of applicability of MOX design systems with the 318 experiments evaluated. When evaluated separately using S/U techniques, none of the 318 experiments satisfied the applicability criteria for a high-density (i.e., > 10 gm/cc) subset of MOX design applications. However, as many as 20 experiments could be shown to satisfy a slightly relaxed acceptance criteria and it was shown that the applicability measures were substantially improved as the MOX powder mass was reduced from the critical condition for this design system subset. For example,

46 benchmark experiments met the applicability criteria for the smallest reduced mass subcritical system.

Upon further investigation of the critical configuration of the high-density MOX powder application, it was determined that this system exhibits unique energy-dependent sensitivities in the fast energy range for several important reactions including ^{239}Pu fission and ^{238}U capture. It is these particular reactions that are likely responsible for the lower correlation between the critical experiments and the design application. For the reduced mass configurations, the energy-dependent sensitivities in these reactions are similar to those of the benchmark experiments, resulting in improved correlation.

1. INTRODUCTION

Sensitivity and Uncertainty (S/U) methods, recently developed at Oak Ridge National Laboratory (ORNL) have been demonstrated to determine the applicability of critical benchmark experiments to the criticality code validation of design systems. These methods, although still under development, have been recently published in several sources.[2-9] Development of the techniques used in this report was conducted through joint support from the United States Department of Energy (U.S. DOE) and the Nuclear Regulatory Commission (NRC) to provide a physics-based approach for the establishment of the area of applicability of critical experiments per the requirements of ANSI/ANS-8.1.[10] Use of these methods may allow users to interpolate and extrapolate the traditional area of applicability (AOA) of a given set of critical experiments to include new application areas that may not have been anticipated during the experiment design.

The new S/U analytical tools include the SEN1 and SEN3 sensitivity analysis sequences, which will be available with the next release of the **S**tandardized **C**omputer **A**nalyses for **L**icensing **E**valuation (SCALE) code system.[1] These analysis sequences compute the relative change in the system neutron multiplication factor, k_{eff}, which would be observed for perturbations in the group-wise neutron cross-section data for each reaction of each nuclide in the system. The CANDE code uses sensitivity data determined separately for the design system applications and the individual experiments, along with the cross-section-covariance data, to calculate integral parameters which give a measure of the similarity between a particular design system and an experimental benchmark. A high-valued integral parameter for an experiment-application pair indicates that the experiment demonstrates similar properties to the application. Thus, the experiment is applicable for the criticality code validation of the design system. A theoretical basis for the S/U techniques applied in this report is given in Sect. 2.

This report pertains to two of the five AOAs identified by the licensee [Duke, Cogema, Stone and Webster (DCS)] for the validation of criticality codes in the design of the Mixed-Oxide Fuel Fabrication Facility (MFFF). The five AOAs are as follows:

1. Pu-nitrate aqueous solutions (homogeneous systems),
2. Mixed-oxide (MOX) pellets, fuel rods and fuel assemblies (heterogeneous systems),
3. PuO_2 powders,
4. MOX powders, and
5. Aqueous solutions of Pu compounds (Pu-oxalate solutions).

This report addresses a S/U analysis pertaining to AOA 3, PuO_2 powders, and AOA 4, MOX powders. AOA 3 and AOA 4 are the subject of this report since the other AOAs (solutions and heterogeneous systems) appear to be well represented in the documented benchmark experiments used in the criticality safety community. Prior to this work, DCS used traditional criticality validation techniques to identify numerous experimental benchmarks that are applicable to AOAs 3 and 4. Traditional techniques for selection of applicable benchmark experiments essentially consist of evaluating the area of applicability for important design parameters (e.g., Pu content or average neutron energy) and ensuring experiments have similar characteristics that bound or nearly bound the range of conditions requiring design analysis. DCS provided ORNL

with compositions and dimensions for critical systems used to establish preliminary mass limits for facility powder and fuel pellet handling areas corresponding to AOAs 3 and 4.

ORNL has reviewed existing critical experiments to identify those, which, in addition to those provided by DCS, may be applicable to the criticality code validation for AOAs 3 and 4. A S/U analysis was then performed to calculate the integral parameters used to determine the similarity of each critical experiment to each design system provided by DCS.

This report contains a review of the S/U theory, a description of the design systems, a brief description of the critical experiments evaluated for applicability, and the results of the S/U analysis determining the applicability of each experiment to each application.

2. SENSITIVITY AND UNCERTAINTY BASED CRITICALITY VALIDATION TECHNIQUES

This section describes the development of S/U methods to gauge the similarity of systems. A theoretical development of the calculation of the sensitivity coefficients and development of sensitivity-only and S/U based integral parameters to quantitatively assess the similarity of systems are given below. The development of the current limiting values to determine system similarity is reviewed, and a summary of the S/U analysis parameters is presented.

2.1. SENSITIVITY THEORY

Sensitivity coefficients are defined physically such that they represent the percentage effect on some response due to a percentage change in an input parameter. For fissionable material systems, one of the appropriate responses is the system k_{eff} value, relative to input parameters of interest (i.e., the nuclear reaction probabilities or cross sections). These sensitivity coefficients are typically presented as "profiles," where the change in k_{eff} due to cross sections is given as a function of the energy of the cross section. These sensitivity profiles can be generated for each material in the system and may include various nuclear reactions (e.g., scatter, absorption, fission) as well as the neutron energy distribution from fission, χ, and average number of neutrons emitted per fission, $\overline{\nu}$.

The techniques used in this work to generate sensitivity information are based on the widely used adjoint-based perturbation theory approach.[11-14] The full derivation of the general procedure will not be given here; however, the specific theory for the generation of k_{eff} sensitivities is given below. For the full derivation of the general sensitivity equations the reader is referred to Ref. 15.

Considering the Boltzmann transport equation written in the form:

$$[A - \lambda B]\phi = 0 , \tag{1}$$

where A and B are loss and production operators, ϕ is the neutron flux, and λ is $1/k_{eff}$, and a perturbed system

$$[A' - \lambda' B']\phi' = 0 , \tag{2}$$

the equation adjoint to Eq. (1) is

$$[A^* - \lambda B^*]\phi^* = 0 , \tag{3}$$

where ϕ^* is the adjoint flux or importance function and A^* and B^* are the adjoint operators corresponding to A and B.

Mulitplying Eq. (2) by ϕ^*, and integrating over all phase space yields

$$\langle \ \phi^*(A' - \lambda'B')\phi' \rangle = 0. \tag{4}$$

Defining:

$$A' = A + dA$$
$$B' = B + dB \tag{5}$$
$$\lambda' = \lambda + d\lambda$$

and using the property of adjointness for the operators A, A^* and B, B^*, it can be shown that

$$\langle \phi^*(dA - \lambda\,dB - B d\,\lambda - d\,\lambda dB)\phi' \rangle = 0. \tag{6}$$

Ignoring second-order terms $(d\lambda dB)$, substituting ϕ' with ϕ, and solving for the inverse k_{eff} perturbation yields

$$d\lambda/\lambda = \langle \phi^*(dA - \lambda dB)\phi \rangle / \langle \phi^*(\lambda B)\phi \rangle. \tag{7}$$

Hence, the sensitivity of λ, with respect to the reaction x cross section, Σ_x, becomes

$$\frac{d\lambda/\lambda}{d\Sigma_x/\Sigma_x} = \frac{\Sigma_x}{\lambda}\ \frac{\langle \phi^*(dA/d\Sigma_x - \lambda\,dB/d\Sigma_x)\phi \rangle}{\langle \phi^*(B)\phi \rangle}. \tag{8}$$

Note that since $\lambda = 1/k_{eff}$, then $d\lambda/\lambda = -dk_{eff}/k_{eff}$ such that the above equation is essentially the defining equation for the k_{eff} sensitivity, S_x, where

$$S_x = \frac{dk_{eff}/k_{eff}}{d\Sigma_x/\Sigma_x} = \frac{-d\lambda/\lambda}{d\Sigma_x/\Sigma_x}. \tag{9}$$

In practice, the dA and dB terms in Eq. (8) are simple functions of the scattering, capture, and fission cross-section data. The evaluation of Eq. (8) then becomes an integration of the forward and adjoint fluxes and the cross sections over the entire phase space.

Typically, the energy dependence of the cross-section data is represented by averaging the S_x quantities over an energy group i, represented as Σ_{x_i}. Insertion of these group quantities into Eq. (9) yields the definition of a sensitivity "profile," $S_{x_i} = \left(dk_{eff}/k_{eff} \right) / \left(d\Sigma_{x_i}/\Sigma_{x_i} \right)$, where i is varied to obtain the sensitivity for all groups, which span the energy range of interest.

2.2. SENSITIVITY-BASED INTEGRAL PARAMETERS

The sensitivity profiles provide a great deal of information about the particular system, because they predict the effect on k_{eff} for differential changes in each of the cross-section data components. However, the amount of information is too large to be of general use. Some type of automated method for representing these sensitivities is necessary to reduce the amount of information to a few easily interpreted parameters. The development of a number of different sensitivity-based integral parameters has been studied and reported in Refs. 3, 5 and 6. The objective was to produce a single parameter that would quantify the similarities between two systems, such that this single parameter could be used for determination of system similarity and as a trending parameter to support interpolation and extrapolation.

An integral parameter to measure the similarity of systems based on the magnitude and shape of the sensitivity profiles for two systems has been demonstrated to quantitatively measure the applicability of one system for the validation of the other.[5] These sensitivity-based parameters, denoted as E, correspond to the summation of the product of the sensitivity coefficients for two systems over energy groups and nuclides, normalized such that when summed over nuclides and reactions, an E value of 0 indicates the systems are totally dissimilar, and an E value of 1 indicates the two systems are precisely the same. The E values are defined as:

$$E_f = M^{-1} \sum_{j=1}^{N} \sum_{i=1}^{g} S_{faij} S_{feij} \, ,$$

$$E_c = M^{-1} \sum_{j=1}^{N} \sum_{i=1}^{g} S_{caij} S_{ceij} \, ,$$

$$E_s = M^{-1} \sum_{j=1}^{N} \sum_{i=1}^{g} S_{saij} S_{seij} \, ,$$

where

$$M = \sum_{x} \left\{ \sum_{j=1}^{N} \sum_{i=1}^{g} \left(S_{xaij} \right)^2 \sum_{j=1}^{N} \sum_{i=1}^{g} \left(S_{xeij} \right)^2 \right\}^{1/2}$$

and S is the sensitivity of k_{eff} for the design system application, a, or experimental configuration, e, to the fission, capture and scattering cross sections (f, c and s respectively) for energy group i and nuclide j;

$$E_{sum} = E_f + E_c + E_s . \tag{10}$$

Mathematically, an E_{sum} value as low as -1 could be generated, but this would be the result of a rare combination of system sensitivities. As with the case of an E value of 0, this would indicate

that the systems are dissimilar. Thus, two systems exhibiting comparable integral responses in k_{eff} due to differential changes in the cross-section data, are considered to be similar.

The E_{sum} parameter is considered "global" in nature, in that a single quantity identifies similarity between two systems based only on the magnitude and shape of the sensitivity profiles for fission, capture and scatter. It is also possible and sometimes desirable to produce analogous values for each isotope-reaction pair, such that similarity information can be computed on a differential level. For this purpose, an additional parameter dE is defined from the equations above by omitting the nuclide and reaction summations in the numerator and the reaction summation in the denominator. Thus, the dE value for reaction x of nuclide j between the application a and the experiment e is defined as:

$$dE_{xeaj} = \frac{\sum\limits_{i=1}^{g} S_{xaij} S_{xeij}}{\left(\sum\limits_{j=1}^{N}\sum\limits_{i=1}^{g} (S_{xaij})^2 \sum\limits_{j=1}^{N}\sum\limits_{i=1}^{g} (S_{xeij})^2 \right)^{1/2}} \; . \tag{11}$$

The dE values relate, on a system-to-system basis, the similarity of various nuclide-reaction pairs. These values are normalized such that, when an application is compared to itself, the sum over isotopes for a given reaction-type (i.e., capture, fission, scatter) is unity. This allows for similarity determinations for that reaction among various isotopes.

With the dE parameter, a detailed analysis of the physics of the systems can be conducted. The magnitudes of the dE values show the relative contribution to E for each nuclide with respect to its capture, fission, or scattering reactions. In addition, since the normalization requires that the sum over a given reaction will only be unity if the two systems are exactly the same, the sum over the dE values for each reaction gives an additional indicator of the systems' similarity. A method of utilizing this information in a simple manner is to define a $T(E)$ value, which is the ratio of the dE value relating the two systems to the dE value of the application system to itself. Thus, the $T(E)$ value relating application a to experiment e for reaction x of nuclide j is

$$T(E)_{xeaj} = \frac{dE_{xeaj}}{dE_{xaaj}} \quad . \tag{12}$$

This $T(E)$ quantity has a value less than unity if the nuclide/reaction pair is less important in the benchmark experiment than the application. $T(E)$ is greater than or equal to unity if the importance of the nuclide-reaction pair in the benchmark experiment is equal to or greater than the importance in the application. Thus, the number of benchmark systems with T values near or greater than unity is a good indicator of benchmark coverage for a given nuclide-reaction pair. Interestingly, this test is appropriate even if the material is not an important material in the application.

2.3. UNCERTAINTY-BASED INTEGRAL PARAMETERS

An alternative and complementary approach to exploring the similarity of systems based solely on the use of sensitivity data is the use of uncertainty analyses. The procedure presented here is the same as that developed in Ref. 3 and is included here for the convenience of the reader. This procedure involves the propagation of estimated cross-section uncertainty information to the calculated k_{eff} value of a given system via the sensitivity coefficients. Mathematically, this is accomplished by a quadratic product of the group-wise sensitivity profile vectors by isotope and reaction type with the cross-section uncertainty matrices by nuclide and reaction type. The result of this procedure is not only an estimate of the uncertainty in the system k_{eff} due to cross sections, but also an estimate of the correlated uncertainty between systems. These correlated uncertainties can be represented by correlation coefficients, which represent the degree of correlation in the uncertainties between the two systems. This parameter, denoted as c_k, not only has the desirability of a single quantity relating the two systems, but also measures the similarity of the systems in terms of uncertainty, not just sensitivity. These correlation coefficients are particularly useful when used in traditional trending analyses for criticality safety validation. When used as a trending parameter in these analyses, the correlation coefficient should relate to the degree in which the uncertainties in the critical benchmarks are coupled with the uncertainties in the application of interest. This coupling with the common uncertainties in the various systems is expected to closely mimic the coupling in predicted biases between the various systems, since they should both be related to the cross-section uncertainties. The underlying assumption in this approach is that the cross-section uncertainty data for all nuclides and reactions of interest are tabulated and processed for use by these procedures. However, tabulated cross-section-covariance data are not available for all nuclide-reaction pairs. Nuclide-reaction pairs without tabulated data are omitted from this analysis, but it is assumed that the cross-section data values from these pairs are well known, and thus, they present a negligible contribution to the uncertainty-based analysis.

Two steps are required in the determination of the uncertainties in the calculated values of the system multiplication factor: (1) the estimation/processing of uncertainties in the cross-section data and (2) the propagation of those uncertainties to the system k_{eff} value. The techniques for processing cross-section uncertainty data are well known[16,17] and will not be discussed here. It should be noted that covariance data in ENDF/B-V is limited to select isotopes. However, those data that are available have been processed for use with these techniques.

Once uncertainty information for the cross sections for all nuclides and reaction processes that are important to the systems become available for analysis, it is possible to estimate the uncertainty in the calculated system multiplication factor due to these data uncertainties. Previous investigations of the propagation of cross-section uncertainties to computed values for uranium systems have demonstrated that the uncertainty in k_{eff} ranges from < 1% for well moderated systems to nearly 2% for dry systems.[3]

When the matrix of uncertainty information for all of the cross sections is denoted as $C_{\alpha\alpha}$, and the sensitivity matrix relating changes in each constituent material and process to the system k_{eff} is labeled as S_k, the uncertainty matrix for the system k_{eff} values, C_{kk}, is given as

$$C_{kk} = S_k C_{\alpha\alpha} S_k^\dagger, \tag{13}$$

where $\dagger$ indicates a transpose.

The S_k is $I \times N$ matrix, where I is the number of critical systems being considered, N is the number of nuclear data parameters in the problem. Typically, N is the number of nuclide-reaction processes times the number of energy groups. The $C_{\alpha\alpha}$ matrix is an $N \times N$ matrix, with the resulting $I \times I$ C_{kk} matrix. The C_{kk} matrix consists of variance values σ_i^2 for each of the critical systems under consideration (the diagonal elements), as well as the so-called "covariance" between systems σ_{ij}^2 (the off-diagonal elements). These off-diagonal elements represent the shared or common variance, hence the term covariance, between any two systems. For presentation, these off-diagonal elements are typically divided by the square root of the corresponding (same row) diagonal elements (i.e., the respective standard deviations) to generate a correlation coefficient matrix. Thus, the c_k coefficients are defined as

$$c_k = \sigma_{ij}^2 \big/ \left(\sigma_i \sigma_j \right) \tag{14}$$

such that each c_k value represents the correlation coefficient between uncertainties in system i and system j.

These correlations arise due to the fact that the uncertainties in the k_{eff} values for two different systems are related, since they contain the same materials. Cross-section uncertainties will propagate to all systems containing these materials. Systems with the same materials and similar spectra would be correlated, while systems with different materials or differing spectra would not be correlated. The interpretation of the correlation matrix is the following: a value of 0 represents no correlation between the systems, a value of 1 represents full correlation between the systems, and a value of −1 represents a full anti-correlation.

Similar to the dE values defined in Sect. 2.2, dc_k values, the individual components of c_k, are defined for comparison of specific nuclide-reaction pairs between a given application and experiment. However, it should be noted that the dc_k parameter does not utilize the cross-section-covariance data to the fullest extent. The covariance between reactions of the same nuclide is utilized, but any covariance relating one nuclide to another is ignored in the dc_k calculation. These covariances are accounted for in the system-wide c_k parameter. A $T(c_k)$ parameter, shown in Eq. (15) is defined as the ratio of the dc_k value for an experiment compared to an application to the dc_k value of the application compared to itself. Thus, a $T(c_k)$ value of 1.0 or higher indicates

that for a given nuclide reaction, the variance of the experiment is as great or greater than that of the application.

$$T(c_k)_{xeaj} = \frac{dc_{k_{xeaj}}}{dc_{k_{xaaj}}}$$ (15)

2.4. AREA OF APPLICABILITY USING INTEGRAL PARAMETER TECHNIQUES

In a previous report,[3] the criterion for the acceptance of a benchmark for the validation of a design system was established such that experiments exhibiting a c_k value of 0.8 or higher could be used for the validation of the design system. This criterion was chosen based on two methods of evaluation. The first was objectively viewing the sensitivity profiles to determine which systems appear to exhibit similar properties. The systems that exhibited the most similarities were those with a c_k value of 0.8 or higher. The second method for establishing the criterion was the divergence of the computational bias predicted by the Generalized Linear Least Squares Methodology (GLLSM) procedure. Through this procedure, the GLLSM code was used to predict the computational bias of a system based on differing sets of experimental benchmarks. First, a large number of critical systems, with a wide range of c_k values, were included in the evaluation, and a bias was computed. Next, systems with c_k values of 0.9 or greater were removed from the experimental set, thus the experiment set included only those experiments with c_k values of 0.89 or lower. No change in the computational bias calculated by GLLSM was observed. A third GLLSM evaluation was performed using only experiments exhibiting a c_k value of 0.79 or lower. In this case, the computational bias computed by GLLSM varied from the previous two calculations by approximately 0.5%. A similarly skewed bias was found when only including systems with a c_k of 0.69 or lower. Thus, it is concluded in Ref. 3, there is a clear break in the behavior of systems at a c_k value of 0.8, and this should be used as the criterion for applicability.

The procedures for determining the applicability of a benchmark dataset for a particular design application using c_k and an outmoded parameter, D_{sum}, which was an early sensitivity-only based integral parameter, are clearly outlined in Ref. 3. Currently, the E parameter is recommended for the supersession of the D parameter. The trending values of E have proven very similar to those of c_k, and thus the recommended limits for validation are the same as those developed for c_k. Two systems are considered to be similar if the c_k or E_{sum} value relating the two systems is 0.8 or higher.

Thus, the recommended procedure for ensuring the applicability of the benchmark dataset in criticality safety validation problems is as follows:

1. Produce sensitivity coefficients for all benchmark experiments and design systems,

2. Quantify values of c_k, dc_k, $T(c_k)$, E, dE, and $T(E)$ relating each application to the entire benchmark set,

3. Count the number of systems with c_k and/or E values > 0.8 (~15–20 systems are needed for validation), and

4. For important nuclide-reaction pairs, count the number of systems with $T(c_k)$ and/or $T(E)$ values > 0.95 (~5–10 systems are needed).

The number of systems and the acceptance criterion for $T(c_k)$ and $T(E)$ values are not rigorously defined. These values are based on experience with other parameters and may change over time with additional experience with these parameters.

A previous application of the S/U methods for systems containing plutonium revealed that the c_k correlation coefficient provides a more accurate measure of system similarity than does the E parameter.[4] The difference in the performance of c_k and E_{sum} is attributed to anti-correlation in the cross-section data for some plutonium isotopes. As a result of these anti-correlations, differences observed in the sensitivity data that would result in lower E_{sum} values will not reduce the value c_k by the same magnitude. Thus, in this study, only the c_k values will be reported.

2.5. SUMMARY OF S/U ANALYSIS TECHNIQUES

Several methods of using S/U analysis to establish system similarity are presented in this section. The integral parameter techniques are used to generate relational parameters based only on the sensitivity data. The E_{sum} parameter is used to assess system similarity on a system-wide basis. Related to E_{sum}, the dE and $T(E)$ parameters are used to assess nuclide-reaction-specific coverage of an application by an experiment. In addition to the sensitivity data, use of cross-section uncertainty data is also employed in the generation of the c_k parameter. As with E_{sum}, the c_k parameter is used to assess similarity on a system-wide basis. However, the similarity assessment is based on the sensitivity-weighted cross-section uncertainties common to the two systems. Also, the dc_k and $T(c_k)$ parameters can be used to determine nuclide-reaction-specific coverage. Each of these parameters is summarized in Table 1.

Table 1. Summary of S/U parameters

Parameter	Description	Recommended value for coverage	Sensitivity based	Uncertainty based	Reaction specific
E_{sum}	Normalized sum of the product of the group-wise sensitivity coefficients for a given application and experiment summed for fission, capture and scattering.	≥ 0.8 for 15–20 systems	√		
dE	Nuclide-reaction-specific normalized sum of the product of group-wise sensitivity coefficients for a given application and experiment. Allows for similarity determinations for specific nuclide-reaction pairs. Available for scatter, capture and fission reactions.		√		√
$T(E)$	Ratio of a particular dE value for a given application-experiment pair to the dE value of the application as compared to itself. Indicates the validation coverage for the particular nuclide-reaction pair for the application by the experiment.	≥ 0.95 for 5–10 systems	√		√
c_k	Correlation coefficient relating the uncertainty in k_{eff} due to uncertainties in the cross-section data common to the application and the experiment.	≥ 0.8 for 15–20 systems	√	√	
dc_k	Nuclide-reaction-specific correlation coefficient relating the uncertainty in k_{eff} due to uncertainties in the nuclide-reaction-specific-cross-section data common to the application and experiment. Allows for similarity determinations for specific nuclide-reaction pairs. Available for scatter, capture and fission reactions.		√	√	√
$T(c_k)$	Ratio of a particular dc_k value for a given application-experiment pair to the dc_k value of the application as compared to itself. Indicates the validation coverage for the particular nuclide-reaction pair for the application by the experiment.	≥ 0.95 for 5–10 systems	√	√	√

3. PROTOTYPICAL SENSITIVITY AND UNCERTAINTY ANALYSIS CODES FOR CRITICALITY SAFETY WITH THE SCALE CODE SYSTEM

Two prototypical sensitivity analysis sequences for criticality safety have recently been developed for the SCALE code system at ORNL. The need for modern tools to produce the sensitivity data necessary for the S/U analysis techniques described in Sect. 2 of this report motivated the development of these sequences. Both of these sequences are applications of the first-order linear perturbation theory as was used in the one-dimensional (1-D) FORSS code system.[15] The SEN1[18] sequence involves 1-D deterministic neutron transport calculations using XSDRNPM. The SEN3[19] sequence involves three-dimensional (3-D) Monte Carlo neutron transport calculations using KENO V.a. Each of these sequences and the types of results they produce are described below. As these analysis sequences have been documented in the references noted above, this section will only provide a brief overview of their capabilities, with special emphasis on previously unpublished capabilities. The SEN1 and SEN3 analysis sequences are expected to be publicly available with the release of SCALE-5.

3.1. SEN1 SEQUENCE

Using the SCALE philosophy and/or protocol as a guide, a 1-D sensitivity sequence, SEN1, was produced. It generates sensitivity coefficients which represent the percentage change in the system k_{eff} for a percentage change in the cross-section value in a given energy group for each nuclide-reaction pair. The SEN1 sequence performs standard resonance processing tasks, and then determines, using 1-D transport theory, the forward and adjoint angular fluxes and flux moments needed for sensitivity coefficient generation. The XSDRNPM code, which is used extensively within the SCALE system, is used for the forward and adjoint neutron transport calculations. The sequence then calls the Sensitivity Analysis Module of SCALE (SAMS), which computes the sensitivity coefficients.

The user input to SEN1 is very similar to the user input of the SCALE shielding analysis sequence, SAS1, except that, since k_{eff} sensitivities do not require a fixed source, a source input is not required. The SEN1 input contains the standard composition description that is common to all SCALE modules, followed by a simple geometry model for the problem. SEN1 uses any of the types of resonance shielding calculations available in SCALE including INFHOMMEDIUM, LATTICECELL and MULTIREGION. For the first option, no resonance shielding is performed; the second technique treats resonance-shielding effects in pin-lattice geometry cases; the third technique gives the user more flexibility in defining the geometry in which the resonance calculations are performed. The SEN1X sequence calculates cell-weighted cross sections with XSDRNPM prior to performing the 1-D criticality calculations.

3.2. SEN3 SEQUENCE

The SEN3 sequence calculates sensitivity coefficients using 3-D Monte Carlo neutral particle transport with KENO V.a. The input for SEN3 is very similar to the CSAS25 sequence

of SCALE commonly used for criticality safety analysis. SEN3 performs resonance-shielding calculations using the same options as SEN1. Forward and adjoint angular neutron fluxes are obtained from an enhanced version of KENO V.a that employs a novel approach to produce the angular fluxes necessary for sensitivity analysis. Once the fluxes are obtained, the SAMS module calculates the sensitivity coefficients from this data and the problem dependent cross-section data. The SAMS module also propagates the uncertainty in the sensitivity coefficients due to the Monte Carlo uncertainties.

A significant advantage in using SEN3 is that the input is very similar to that of CSAS25. Thus, with only minor modifications, existing criticality models used for CSAS25 analyses can be used for sensitivity analysis using SEN3.

3.3. SENSITIVITY TO RESONANCE-SHIELDED MULTIGROUP CROSS SECTIONS

Previous verification results of SEN1 and SEN3 demonstrated that the sensitivity coefficients could be over predicted, especially for scattering-type reactions for well-moderated systems.[18,19] This effect is due to changes in the self-shielded multigroup neutron cross-section data caused by changes in the fine-structured neutron energy spectrum resulting from perturbations in nuclide concentrations.[20] Updated versions of BONAMI and NITAWL-II have recently been developed for use with SEN1 and SEN3 to account for these effects. The documentation of this work is beyond the scope of this report but will be the subject of future publications. All sensitivity data used in this report was calculated with the use of these new techniques through the enhanced resonance processing code BONAMIST and NITAWLST.

3.4. SENSITIVITY DATA

The standard output files from both SEN1 and SEN3 contain sensitivity coefficients presented as a total sensitivity, which is integrated over all cross-section energies for a particular reaction type of an isotope. These are presented on a region-dependent basis as well as region-integrated, which provides a single sensitivity coefficient for each reaction of a particular isotope integrated over the entire system. Each code also generates a text file containing the sensitivity profiles in which the relative change in k_{eff} is displayed for each reaction type of each isotope for each energy group. Sensitivities are generated for a wide variety of nuclear reactions including scattering, fission, capture, absorption, $\bar{\nu}$, χ and the total of all reactions.

3.5. CANDE

The CANDE (*c* and *E*) code was created to perform the integral parameter analyses using the sensitivity data generated from the SEN1 and/or SEN3 sequences. CANDE produces the c_k, E, dE, dc_k, $T(E)$ and $T(c_k)$ parameters described in Sect. 2 for one or more applications in reference to an experimental database chosen by the code user. CANDE also computes the completeness parameter R, which assesses the coverage of each application by the entire benchmark suite. The development and use of the completeness parameter is given in Appendix A.

4. SAMPLE DESIGN APPLICATIONS FOR THE MIXED-OXIDE FUEL FABRICATION FACILITY

As indicated in Sect. 1, the MFFF licensee, DCS, has identified five AOAs for the validation of criticality codes in the design of the facility. This report addresses a S/U analysis pertaining to AOA 3, PuO_2 powders, and AOA 4, MOX powders. DCS provided the following data corresponding to AOA 3 and AOA 4. The data is representative of the expected bounding compositions encountered in MFFF design applications.

Many MFFF design applications involve process units and areas where mass and moderation limits are imposed. Mass limits are established based on simple homogeneous powder-form systems with simple geometry (i.e., single reflected and unreflected slabs, cylinders and spheres). Three oxide media in homogeneous form are considered for evaluation as follows:

- PuO_2 (100%), included in AOA 3,
- MOX with 22 wt % PuO_2, included in AOA 4,
- MOX with 6.3 wt % PuO_2, included in AOA 4.

The Pu isotopic composition assumed in all design applications under AOAs 3 and 4 is 96 wt % ^{239}Pu and 4 wt % ^{240}Pu. This isotopic distribution is considered to bound the actual expected range of Pu isotopic distributions summarized as follows:

- $^{236}Pu < 1$ ppb,
- $^{238}Pu < 0.05$ wt %,
- 90 wt % $< {}^{239}Pu < 95$ wt %,
- 5 wt % $< {}^{240}Pu < 9$ wt %,
- $^{241}Pu < 1$ wt %,
- $^{242}Pu < 0.1$ wt %.

In addition to Pu isotopes, PuO_2 (100%) received and handled at the MFFF will also contain up to 2 wt % U enriched up to 93.2 wt % ^{235}U and 0.7 wt % ^{241}Am in addition to chemical impurities not explicitly modeled in fissile systems.

Powder density assumptions vary from process to process. Design assumptions for maximum powder density generally range from 3.5 g/cm^3 to 7.0 g/cm^3 (possibly 8.3 g/cm^3).

Moderator content in powder handling areas is typically limited to < 5 wt % H_2O. Although other moderator content conditions are evaluated (0, 1 and 3 wt %), the 5 wt % value is generally evaluated as a worst-case moderator content assumption.

The fuel compositions and reflector specifications of seven design applications are given below. The applicability of critical experiments to each design system is evaluated in subsequent sections of this report. Three applications shown in Table 2 are critical configurations representative of AOA 3, PuO_2 powders. Four material specifications, shown in Table 3, are

representative of AOA 4, MOX powders. Each of the four material compositions given in Table 3 has a critical radius listed. The fourth material, high-density MOX powder, also has three subcritical configurations listed. Although modeled as a homogeneous sphere, the actual design system with the material specified as AOA 4-4 will involve loose pellets, which will be under strict mass controls. Mass limits, based on the total Pu content, have been used to develop subcritical models consisting of this high-density MOX material. Thus the three subcritical configurations are given identifiers denoting the mass of Pu in the system in kilograms (e.g., AOA 4-4-P163 contains 163 kg of Pu).

Table 2. Proposed design application specification for AOA 3 (PuO_2 powders) of MFFF

Identifier	Composition (wt %)		Powder density (g/ml)	H_2O content (wt %)	Reflector	Fuel radius of critical sphere (cm)
AOA 3-1	100% PuO_2	96% ^{239}Pu 4% ^{240}Pu	3.5	5%	30 cm H_2O	15.7
AOA 3-2	100% PuO_2	96% ^{239}Pu 4% ^{240}Pu	3.5	16.6%	30 cm H_2O	12.1
AOA 3-3	100% PuO_2	96% ^{239}Pu 4% ^{240}Pu	7.0	1%	30 cm H_2O	7.65

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Table 3. Proposed design application specification for AOA 4 (MOX powders) of MFFF

Identifier	Composition (wt %)		Mass of Pu (kg)	Powder density (g/ml)	H_2O content (wt %)	Reflector	Fuel radius of modeled sphere (cm)
AOA 4-1	22% PuO_2	96% ^{239}Pu / 4% ^{240}Pu	100.53	5.5	5%	30 cm H_2O	23.64 (critical)
	78% UO_2	0.3% ^{235}U / 99.7% ^{238}U					
AOA 4-2	22% PuO_2	96% ^{239}Pu / 4% ^{240}Pu	88.28	5.5	5%	60 cm depleted uranium	22.0 (critical)
	78% UO_2	0.3% ^{235}U / 99.7% ^{238}U					
AOA 4-3	6.5% PuO_2	96% ^{239}Pu / 4% ^{240}Pu	124.07	6.96	5%	30 cm H_2O	37.0 (critical)
	93.5% UO_2	0.3% ^{235}U / 99.7% ^{238}U					
AOA 4-4	6.5% PuO_2	96% ^{239}Pu / 4% ^{240}Pu	453.62	10.2	1%	30 cm H_2O	57.0 (critical)
	93.5% UO_2	0.3% ^{235}U / 99.7% ^{238}U					
AOA 4-4-P163	6.5% PuO_2	96% ^{239}Pu / 4% ^{240}Pu	163	10.2	1%	30 cm H_2O	40.53 (subcritical)
	93.5% UO_2	0.3% ^{235}U / 99.7% ^{238}U					
AOA 4-4-P40	6.5% PuO_2	96% ^{239}Pu / 4% ^{240}Pu	40	10.2	1%	30 cm H_2O	25.37 (subcritical)
	93.5% UO_2	0.3% ^{235}U / 99.7% ^{238}U					
AOA 4-4-P8	6.5% PuO_2	96% ^{239}Pu / 4% ^{240}Pu	8	10.2	1%	30 cm H_2O	14.84 (subcritical)
	93.5% UO_2	0.3% ^{235}U / 99.7% ^{238}U					

5. DEVELOPMENT OF CRITICAL EXPERIMENT DATABASE

The key to any criticality safety validation procedure is the generation of a database of critical benchmark experiments that covers a broad range of systems that are in some way similar to the particular application(s) of interest. At the onset of this work, DCS introduced a database of critical experiments for each AOA evaluated in this study. Based on the expert judgment of criticality safety practitioners and traditional trending methods, DCS recommended 46 critical benchmarks for AOA 3 and 14 for AOA 4. With the anticipation that the S/U analysis would extend the area of applicability of existing experiments, ORNL used more relaxed criteria in the selection of critical benchmarks. Thus, 318 experiments, including the 60 initially identified by DCS, have been complied into an experimental database for use with this study. A summary description of each set of experiments is given in Table 4, and experiment-specific data are tabulated in Appendix B. The number of benchmark experiments from each experimental series identified by DCS, as applicable to either AOA 3 or AOA 4, is also give in Table 4. In the S/U analyses presented in subsequent sections of this report, integral parameters for each application of interest are generated to determine the similarity of each application to each of these 318 benchmark experiments. The experiments were chosen because of similarity to the design applications described in the previous section, either in material type or in fission energy spectrum. Other experiments were also analyzed; however, they were not included in this database because they were not applicable to either AOA 3 or AOA 4. The benchmark experiments in this database include both plutonium systems, mixed plutonium and uranium systems, and one set of low-enriched uranium systems with low moderation. The benchmark descriptions for the majority of these experiments are provided in the International Handbook of Evaluated Criticality Safety Benchmark Experiments (IHECSBE),[21] which is a product of the International Criticality Safety Benchmark Evaluation Program.* Experiments from the IHECSBE are noted with the parenthetical comment of their handbook designation. Experiments compiled from other sources are specifically noted.

5.1. PLUTONIUM SYSTEMS

Sixty-one plutonium benchmarks are included in the experiment database used for this study. These include metal systems and oxide systems.

5.1.1.   Plutonium Metal Systems

Twenty-six plutonium metal experiments are included in this set of benchmarks. Two bare metal spheres are included: one with a low ^{240}Pu content (4.5 at. %), designated ^{239}Pu Jezebel (PU-MET-FAST-001), and another with a higher ^{240}Pu content (20.1 at. %) designated as ^{240}Pu Jezebel (PU-MET-FAST-002). A set of five experiments using arrays of unmoderated

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* The International Criticality Safety Benchmark Evaluation Program (ICSBEP) is an ongoing effort to identify and evaluate a comprehensive set of critical benchmark data for use by the worldwide criticality safety community. The project involves criticality safety experts and experimental data from several national laboratories in the United States, as well as the United Kingdom, France, Japan, the Russian Federation, Hungary, Korea, Slovenia, Yugoslavia, Spain, and Israel. The work of the ICSBEP is documented as an International Handbook of Evaluated Criticality Safety Benchmark Experiments, which is updated annually.

Table 4. Summary description of benchmark experiments

Experiment identifier	Number of experimental configurations		H/(Pu+U)	Range of EALF (eV)	Description
	Considered in this study	Identified by DCS			
PU-MET-FAST-001	1		0	1.24E+06	Bare metal sphere (4.5 at. % Pu-240)
PU-MET-FAST-002	1		0	1.26E+06	Bare metal sphere (20.1 at. % Pu-240)
PU-MET-FAST-003	5		0	6.24E+05 to 1.24E+06	Unmoderated metal button arrays
PU-MET-FAST-016	6		0	7.78E+03 to 1.17E+04	Moderated metal button arrays
PU-MET-FAST-017	5		0	9.39E+04 to 7.82E+05	Moderated metal cylinder arrays
PU-MET-FAST-033	1		0	4.02E+05	ZPPR-21 Series
PU-MET-FAST-037	7		0	1.82E+04 to 1.48E+05	Moderated metal button arrays
PU-COMP-MIXED-001	5		0.04 to 49.6	1.54E+00 to 9.57E+05	Unreflected polystyrene compacts
PU-COMP-MIXED-002	29		0.04 to 49.6	6.84E-01 to 4.92E+03	Reflected polystyrene compacts
PU-COMP-INTER-001	1		0.37	3.08E+02	Plutonium oxide, graphite, and boron
MIX-SOL-THERM-001	13		44.08 to 418.64	9.25E-02 to 2.84E-01	MOX solution in annular cylinders
MIX-SOL-THERM-002	3		481.37 to 1150.66	4.24E-02 to 4.34E-02	MOX solution in large cylinders
MIX-SOL-THERM-004	9		48.99 to 238.94	6.75E-02 to 3.54E-01	MOX solution in small cylinder
MIX-SOL-THERM-005	7		49.01 to 241.44	6.70E-02 to 3.56E-01	MOX solution in slabs
MIX-COMP-THERM-001	4		3.33 to 17.53	2.11E-04 to 1.61E-03	MOX fuel pin arrays
MIX-COMP-THERM-002	6		1.19 to 3.64	1.38E-01 to 7.73E-01	MOX fuel pin arrays (PNL 30-35)
MIX-COMP-THERM-003	6		1.68 to 10.75	1.01E-01 to 9.06E-01	MOX fuel pin arrays (Saxton)
MIX-COMP-THERM-004	11		2.42 to 5.55	8.02E-02 to 1.46E-01	MOX fuel pin arrays
MIX-COMP-THERM-005	7		2.22 to 11.87	8.30E-05 to 3.82E-04	MOX fuel pin arrays (Plutonium Utilization Program)
MIX-COMP-THERM-008	28		1.77 to 7.31	9.17E-02 to 3.99E-01	MOX fuel pin arrays (Plutonium Utilization Program)
MIX-COMP-THERM-009	6		1.41 to 5.89	9.06E-02 to 5.52E-01	MOX fuel pin arrays (Plutonium Utilization Program)
MIX-COMP-THERM-011	6		11.75 to 21.13	2.50E-01 to 5.66E-01	MOX fuel pin arrays (RAPSODIE)
MIX-COMP-THERM-012	33		39.54 to 101.71	6.62E-02 to 1.40E-01	MOX polystyrene compacts
PU-8-1 to PU-29-9	14	14	2.77 to 7.33	6.30E-01 to 4.14E+01	MOX polystyrene compacts (NSE-61, Ref. 7)
NSE-55, Table 4	22		30.6	1.43E-01 to 1.58E-01	MOX polystyrene compacts with poison plates (Ref. 6)
NSE-55, Table 5	10		2.8	3.85E+01 to 4.39E+01	MOX polystyrene compacts with poison plates (Ref. 6)
BNWL-2129, Table 3	31		30.6	1.43E-01 to 2.57E-01	MOX polystyrene compacts with poison plates (Ref. 8)
BNWL-2129, Table 4	19		7.13 to 9.37	1.51E+00 to 6.13E+00	MOX polystyrene compacts with poison plates (Ref. 8)
MIX-MET-FAST-011	4		0	2.07E+05 to 3.18E+05	ZPPR-21 Series
LEU-COMP-THERM-049	18		2.01 to 3.01	7.94E-01 to 2.36E+00	Low-moderated LEU oxide

plutonium metal buttons, either bare or with one side reflected by polyethylene, were included (PU-MET-FAST-003). A group of 13 experiments using plutonium metal in cans, and placed in $3 \times 3 \times 3$ or $2 \times 2 \times N$ arrays with water moderation and reflection are taken from PU-MET-FAST-016 and PU-MET-FAST-037. Five experiments using moderated arrays of plutonium metal cylinders are included from PU-MET-FAST-017. The final plutonium metal experiment is from PU-MET-FAST-033, and is part of the ZPPR-21 series of experiments, which also include MIX-MET-FAST-011 and HEU-MET-FAST-061. The ZPPR-21 series began with a fissile core containing only plutonium, and gradually substituted highly-enriched uranium metal for some of the plutonium metal until the final configuration contained only uranium.

5.1.2. Plutonium Oxide Systems

A set of 34 experiments involves plutonium oxide that has been mixed with various quantities of polystyrene, and then compacted into cubes. These cubes are stacked in arrays to form critical configurations with or without Plexiglas reflection. Five unreflected experiments are taken from PU-COMP-MIXED-001, and 29 experiments from PU-COMP-MIXED-002. The H/Pu ratios in these compacts range from 0.04 to 49.6, giving a range of fission neutron spectra from fast to thermal.

One benchmark using plutonium oxide, graphite, and boron was included from PU-COMP-INTER-001. This benchmark describes a system with a k_{inf} of 1, and is interpolated from measured reactivity worths for a number of fuel samples with varied boron content. With energy of average lethargy causing fission (EALF) of ~300 eV, this benchmark was chosen to represent the dry plutonium oxide powders in applications 1 through 3.

5.2. MIXED PLUTONIUM AND URANIUM SYSTEMS

Two hundred and thirty-nine mixed plutonium and uranium systems are included in this set of benchmarks. These experiments involve solution systems, fuel pin lattices, solid mixed-oxide systems moderated by polystyrene, and mixed metal systems.

5.2.1. Mixed Plutonium and Uranium Solution Systems

Thirteen experiments with mixed plutonium and uranium solution in annular cylinder geometry are taken from MIX-SOL-THERM-001. The ratio of Pu/(Pu + U) is 0.22 or 0.97, and the concentration of the solution in the annular region is varied from 61 to 489 g (Pu + U)/liter. All experiments use a water reflector.

Three experiments with similar solution in large cylindrical geometry are from MIX-SOL-THERM-002. The objective of these experiments was to obtain data on the minimum fissile concentration for criticality in an effectively infinite cylindrical geometry. The reaction vessel has an inside diameter of 68.68 cm. The concentrations of the solution are 23 and 53 g (Pu + U)/liter with a ratio of Pu/(Pu + U) of 0.52 and 0.23, respectively. All three experiments are water reflected.

Nine experiments from this same series that use small cylindrical geometry are also included from MIX-SOL-THERM-004. The reaction tank has an inside diameter of 35.39 cm

and inside height of 106.60 cm. The concentrations of the solution are 105, 293, and 435 g (Pu + U)/liter with a ratio of Pu/(Pu + U) of 0.4 for all nine experiments. Three measurements have a water reflector, three have a concrete reflector, and three have no reflector.

Seven experiments with mixed plutonium and uranium solution in slab geometry are taken from MIX-SOL-THERM-005. The solution concentration ranged from 105 to 435 g (Pu + U)/liter with a ratio of Pu/(Pu + U) of 0.4. Four experiments were water reflected, and four were bare.

5.2.2. Mixed Plutonium and Uranium Fuel Pin Lattices

Four experiments using natural UO_2-20 wt % PuO_2 (11.5 wt % ^{240}Pu) fuel pins in a square lattice were analyzed (MIX-COMP-THERM-001). These experiments used water reflection, and incorporated polypropylene grid plates to minimize the effect of the grids on the reactivity of the core. The pitch was varied from 0.95 to 1.9 cm.

Six experiments with natural UO_2-2 wt % PuO_2 (8% ^{240}Pu) fuel include square-pitched lattices, with 0.70-in., 0.87-in., or 0.99-in. pitch, in borated or pure water moderator (MIX-COMP-THERM-002). These experiments are also referred to as PNL 30-35 in NUREG/CR-0210 in the CSEWG Thermal Reactor Benchmarks (BNL-19302).

Six more experiments with natural UO_2-6.6 wt % PuO_2 fuel include square-pitched, partial-moderator-height lattices with five lattice pitches of 0.52 in., 0.56 in., 0.735 in., 0.792 in., and 1.04 in. (MIX-COMP-THERM-003). The purpose of these experiments was to verify the nuclear design of the Saxton partial plutonium core, which consisted of MOX assemblies in the central region with peripheral enriched UO_2 assemblies. The experiments with 0.56-in.-pitched lattices were performed with borated or pure water moderator, but the other pitched-lattice experiments were performed only with pure water moderator.

Eleven experiments conducted at the Tokai Research Establishment of JAERI in Japan used natural UO_2 – 3.01 wt % PuO_2 rods in square arrays of varying pitch (MIX-COMP-THERM-004). The plutonium in the fuel pins contained 24 wt % ^{240}Pu.

Forty-one experiments from the Plutonium Utilization Program at Pacific Northwest Laboratories are included (MIX-COMP-THERM-005, MIX-COMP-THERM-008, and MIX-COMP-THERM-009). These experiments were performed using MOX fuel with PuO_2 enrichments varying from 1.5- to 4-wt % PuO_2, and the ^{240}Pu isotopic composition of the plutonium was varied from 8% to 24%. The fuel pins are arranged in hexagonal lattices with varying pitches with the rods uniformly arrayed in such a manner that the core is a right circular cylinder.

Six benchmark experiments using MOX fuel designed for the RAPSODIE fast breeder reactor in Cadarache, France are included from MIX-COMP-THERM-011. The uranium was enriched to 60 wt % ^{235}U, and the plutonium content of the MOX fuel was 25.8 wt %, with 9.72 wt % of the plutonium being ^{240}Pu. The pitch was triangular, and measured either 1.9 cm or 2.5 cm.

5.2.3. Mixed Plutonium and Uranium Solid Systems

Several experiments using various combinations of plutonium oxide, depleted uranium oxide and polystyrene, which had been pressed into compacts and stacked into arrays, are included in the database used in this study. They are included in MIX-COMP-THERM-012 and three other published references that have not yet been included in the IHECSBE. The configurations are similar to those in PU-COMP-THERM-001 and –002, but with MOX instead of plutonium oxide. There are both reflected and unreflected arrays, and some of the stacked arrays contain neutron poison plates.

There are 33 experiments included from MIX-COMP-THERM-012. These configurations contain mixtures of plutonium and depleted uranium oxides containing between 7.6 and 30-wt % plutonium, with H/X ratios from 19.5 to 51.8. Six experiments with 7.6-wt % plutonium used plutonium that contains 23 wt % ^{240}Pu. The other experiments use plutonium with 8 wt % ^{240}Pu. Twenty-seven experiments are Plexiglas reflected, while six are bare.

Fourteen other experiments were performed with a similar range of plutonium oxide concentrations, but with much lower moderation levels (NSE-61).[22] These experiments also utilize compacts with between 7.6 and 30 wt % plutonium, and H/X ratios ranging from 3 to 7. The plutonium contained 11.5 wt % ^{240}Pu. Only the plexiglas-reflected configurations from this reference are included. (These experiments have been tentatively assigned to evaluation number MIX-COMP-INTER-001 in the IHECSBE, but have not been published in the Handbook.) In the attached tables, these experiments are labeled PU-8-1 through –4, PU-15-1, and PU-29-1 through –9.

Thirty-two experiments were performed with MOX-polystyrene compacts in arrays that contained either one or two copper, copper/cadmium, or aluminum plates of varying thickness within the stack.[23] All of these experiments were fully reflected with Plexiglas. Two types of fuel were used in these experiments. The first contained MOX with a plutonium content of 14.6 wt %, of which 7.97 wt % was ^{240}Pu, and with an H/X of 30.6. The second type of fuel contained MOX with a plutonium content of 30.3 wt %, of which 11.5 wt % was ^{240}Pu, and with an H/X of 2.8. Twenty-two experiments contained the fuel with an H/X of 30.6, and ten experiments used the fuel with an H/X of 2.8. These experiments are labeled NSE55T*x-xx* in subsequent sections of this report.

Fifty experiments were performed using these same two fuel compositions, but with other types of neutron poison plates contained with the array stacks. All of these experiments were also fully reflected with Plexiglas.[24] The poison plate materials included Type 304 stainless steel, steel with 1.1 wt % boron, steel with 1.6 wt % boron, boral, lead, depleted uranium, cadmium, and aluminum. Thirty-one independent experiments were performed with the fuel with an H/X of 30.6. In the case of the fuel with an H/X of 2.8, the 19 configurations used some of the fuel with an H/X of 30.6 as a driver. An $8 \times 8 \times 2$ array of the lower-moderated fuel was used above and below the neutron poison plate, and on top of this was placed at least two layers of the higher-moderated fuel. The thickness of driver fuel was varied to achieve criticality with the various neutron poison plate materials and thicknesses. The reference states that the neutron flux in the region containing the poison plate was characteristic of the lower-moderated fuel, and that < 30%

of the fissions occurred in the higher-moderated fuel. However, when using these experiments as critical benchmarks, the importance of the more moderated fuel is significant, and the overall flux is more thermal than the experiments using only the lower-moderated fuel. These experiments are labeled BNWL2129T*x-xx* in subsequent sections of this report.

5.2.4.   Mixed Plutonium and Uranium Metal System

A set of four mixed plutonium and uranium metal systems was analyzed as a means of including homogeneous uranium/plutonium systems with a fast energy spectrum. These experiments are documented in MIX-MET-FAST-011, and are part of the ZPPR-21 series of experiments that also include PU-MET-FAST-033 and HEU-MET-FAST-061. As described previously, the ZPPR-21 series began with a fissile core containing only plutonium, and gradually substituted highly enriched uranium metal for some of the plutonium metal until the final configuration contained only uranium. (The last configuration is described in HEU-MET-FAST-061, and was not included in this database since it did not pertain to any of the applications of interest.) The four experiments in MIX-MET-FAST-011 contain between 41.4 and 7.7 wt % plutonium metal, which included between 6.16 and 11.6 wt % ^{240}Pu. The bulk of the neutron spectrum is in the 100-keV to 4-MeV energy range and the peak is at about 600 keV. Thus, the spectrum is in the fast range, although not as hard as the spectrum in many other fast metal assemblies.

5.3. LOW-ENRICHED URANIUM OXIDE SYSTEMS

In order to include experiments with low-enriched uranium oxide at low moderation levels, 18 experiments from LEU-COMP-THERM-049 were placed in the database. These models primarily assist in validating ^{238}U capture and fission cross sections in the higher-neutron energy region. The experiments were performed under the MARACAS program at the Valduc facility in France. The uranium dioxide was enriched to 5 wt % ^{235}U, and was moderated to an H/X of between 2 and 3. Uranium dioxide powder was moistened and contained in metal boxes, which were placed in various sized arrays on a split table, and the overall configuration was reflected with polyethylene. The overall neutron spectrum is thermal but has a significant intermediate energy component.

6. RESULTS

The objective of this study is to determine which of the 318 critical benchmarks identified in the previous section are applicable for the criticality code validation for AOAs 3 and 4 of the MFFF. To assess the applicability of benchmark experiments to each AOA, several design systems were analyzed that are representative of the compositions and masses expected in the design of the MFFF in each AOA. The applicability of each experiment was determined independently for each design system. Each design system represents a subset of each AOA. The measure of applicability was established in Sect. 2.4 of this report. This criterion is that the c_k correlation coefficient, relating the particular design systems to an experiment, meets or exceeds a value of 0.8. Tabulated results of E_{sum} and c_k values for all applications in relation to all benchmarks identified in Sect. 5 are given in Appendix B.

To compute correlation coefficients, group-wise, nuclide-reaction-specific sensitivity data were required for each of the 318 critical benchmarks and each of the design applications. Each of the critical experiments was modeled explicitly in 3-D using the SEN3 sensitivity analysis sequence of SCALE. Each of the spherical applications was modeled in 1-D using the SEN1 sensitivity analysis sequence of SCALE. Both SEN1 and SEN3 were executed within a pre-release version of SCALE-5 using the 238-group ENDF/B-V data library. The cross-section data were resonance shielded using the BONAMIST and NITAWLST modules.

Subsequent to the generation of the sensitivity data, the CANDE code was used to generate the correlation coefficients relating each application to each of the benchmark experiments. These correlation coefficients are shown in subsequent tables in order of descending values such that the experiments with the highest correlation to the design system are shown first in the tables.

6.1. AOA 3 – PUO$_2$ POWDERS

The S/U analysis of the three applications submitted by DCS as representative of AOA 3 has determined that numerous benchmarks exceeded the 0.8 criterion for c_k for each application. Some important calculated parameters for each application are shown in Table 5. A more detailed description of each application was previously presented in Sect. 4 of this document.

Table 5. Calculated characteristics of design systems from AOA 3

Application	H/Pu	EALF (eV)	k_{eff}
AOA 3-1	1.58	1019	0.9984
AOA 3-2	5.99	94.37	1.001
AOA 3-3	3.04	884.3	1.006

Of the 318 benchmark experiments, 91 were determined to satisfy the criteria of $c_k \geq 0.8$ for at least one of the analyzed design application systems from AOA 3. For the first application in AOA 3, 30 systems exhibit a c_k value of 0.8 or greater. All of the experiments with a c_k value in excess of 0.8 contain plutonium fuel. The majority of the systems are of metal composition with a fast energy spectrum. The experiment designator and c_k values are shown in Table 6 along with other important parameters for each of the systems. For the second application in AOA 3, 61 systems exhibit a c_k value of 0.8 or greater.   Of these 61 systems, 23 are plutonium-only systems and 38 are MOX systems. Data regarding these systems are shown in Table 7. For the third application in AOA 3, 61 systems exhibit a c_k value of 0.8 or greater. Of these 61 systems, 41 are plutonium fueled and 20 contain MOX fuel. Data regarding these systems is shown in Table 8. Note that numerous MOX benchmarks exceed the applicability criterion for these plutonium applications.

The S/U methods identified the majority of the benchmarks chosen by DCS as meeting the 0.8 criterion for c_k. Of the 46 experimental configurations identified by DCS, 38 were confirmed by the S/U methods as applicable to at least one of the design systems representing a subset of AOA 3. Of the 46 experiments, S/U methods identified 18 as meeting the applicability criterion for AOA 3-1, 21 for AOA 3-2, and 36 for AOA 3-3. These experiments are noted in Tables 6–8.

Table 6. Experimental configurations with c_k coefficients ≥ 0.8 for AOA 3-1

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
PMF016-05*	0.8715	0	5.97	7.93E+03	0.9965	0.0006
PMF016-01*	0.8668	0	5.97	1.17E+04	1.0118	0.0006
PMF037-16	0.8625	0	5.97	2.84E+04	0.9996	0.0006
PMF037-15	0.8623	0	5.97	1.82E+04	0.9985	0.0005
PMF003-02	0.8621	0	5.97	6.90E+05	0.9935	0.0007
PMF003-01	0.8617	0	5.97	1.24E+06	0.9937	0.0006
PMF037-07*	0.8614	0	5.97	3.30E+04	0.9984	0.0006
PMF003-03	0.8612	0	5.97	1.24E+06	0.9879	0.0006
PMF001-01	0.8602	0	4.7	1.24E+06	0.9949	0.0007
PMF016-03*	0.8597	0	5.97	8.34E+03	0.9995	0.0007
PMF037-12*	0.8597	0	5.97	2.35E+04	1.0009	0.0006
PMF003-04	0.8596	0	5.97	6.24E+05	0.9926	0.0006
PMF016-04*	0.8589	0	5.97	8.01E+03	0.9982	0.0007
PMF017-01	0.8588	0	5.97	7.82E+05	0.9901	0.0007
PMF037-01*	0.8584	0	5.97	1.48E+05	0.9973	0.0006
PMF003-05	0.8578	0	5.97	1.24E+06	0.9908	0.0007
PMF037-10*	0.8577	0	5.97	2.61E+04	0.9993	0.0006
PMF016-02*	0.8553	0	5.97	8.61E+03	1.0003	0.0006
PMF017-02*	0.855	0	5.97	4.05E+05	0.9932	0.0007
PMF017-03*	0.8541	0	5.97	2.30E+05	0.994	0.0008
PMF017-04	0.8507	0	5.97	4.58E+05	0.991	0.0006
PMF037-05*	0.8497	0	5.97	5.12E+04	0.9977	0.0006
PMF002-01	0.8488	0	20.1	1.26E+06	0.9964	0.0005
PMF016-06*	0.8425	0	5.97	7.78E+03	1.0003	0.0007
PMF017-05*	0.8405	0	5.97	9.39E+04	1.002	0.0006
PCM002-02*	0.8343	0.04	18.35	4.21E+03	1.0308	0.0006
PMF033-01	0.8288	0	5.83	4.02E+05	1.0066	0.0005
PCM002-01*	0.8177	0.04	18.35	4.92E+03	1.0322	0.0007
PCM002-03*	0.8083	0.04	18.35	3.51E+03	1.0262	0.0006
PCM002-04*	0.8077	0.04	18.35	2.57E+03	1.0197	0.0006

*Benchmark experiment identified by DCS as applicable to AOA 3.

Table 7. Experimental configurations with c_k coefficients ≥ 0.8 for AOA 3-2

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
PCM002-06*	0.9893	5	11.46	9.25E+01	1.0234	0.0006
PCM002-07*	0.9880	5	11.46	8.49E+01	1.022	0.0006
PCM002-08*	0.9875	5	11.46	6.80E+01	1.0212	0.0006
PCM002-09*	0.9779	5	11.46	5.68E+01	1.0218	0.0005
PCM001-02*	0.9773	5	11.46	1.73E+03	1.0198	0.0007
PCM001-04	0.9707	15	8.06	3.95E+01	0.9878	0.0007
PCM001-03*	0.9670	15	2.2	3.26E+01	1.0168	0.0008
PCM002-21*	0.9541	15	2.2	6.64E+00	1.0101	0.0006
PCM002-22*	0.9511	15	2.2	6.45E+00	1.0143	0.0007
PCM002-20*	0.9505	15	2.2	6.65E+00	1.0087	0.0005
PCM002-19*	0.9497	15	2.2	6.47E+00	1.0088	0.0006
PCM002-18*	0.9491	15	2.2	6.19E+00	1.0102	0.0006
NSE55T5-07	0.9457	2.8	11.5	4.39E+01	1.0042	0.0005
PCM002-14*	0.9457	15	2.2	5.60E+00	1.0295	0.0006
PU-29-1	0.9456	2.77	11.5	4.14E+01	0.9941	0.0003
NSE55T5-01	0.9453	2.8	11.5	3.97E+01	1.0058	0.0005
PU-29-4	0.9453	2.77	11.5	3.78E+01	0.9932	0.0004
NSE55T5-10	0.9451	2.8	11.5	3.85E+01	1.0036	0.0004
PU-29-3	0.9451	2.77	11.5	4.07E+01	1.0022	0.0005
PU-29-2	0.9450	2.77	11.5	4.03E+01	0.9931	0.0005
PU-29-7	0.9448	2.77	11.5	3.48E+01	0.9944	0.0005
PCM002-15*	0.9446	15	2.2	5.56E+00	1.0283	0.0006
NSE55T5-08	0.9445	2.8	11.5	3.93E+01	1.0026	0.0006
PCM002-16*	0.9444	15	2.2	5.15E+00	1.0235	0.0007
PU-29-5	0.9443	2.77	11.5	3.77E+01	0.9937	0.0003
NSE55T5-05	0.9438	2.8	11.5	4.03E+01	1.002	0.0005
NSE55T5-02	0.9437	2.8	11.5	3.97E+01	1.0028	0.0005
PU-29-8	0.9437	2.77	11.5	3.44E+01	0.9951	0.0005
PU-29-6	0.9432	2.77	11.5	3.67E+01	0.9931	0.0003
PU-29-9	0.9431	2.77	11.5	3.46E+01	0.9987	0.0005
PCM002-17*	0.9426	15	2.2	4.93E+00	1.0073	0.0007

Table 7 (continued)

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
NSE55T5-03	0.9424	2.8	11.5	4.00E+01	1.0049	0.0005
NSE55T5-04	0.9422	2.8	11.5	4.10E+01	1.0048	0.0005
NSE55T5-06	0.9422	2.8	11.5	4.14E+01	1.0045	0.0005
PCM002-12*	0.9419	15	2.2	5.13E+00	1.0273	0.0006
PCM002-11*	0.9390	15	2.2	4.55E+00	1.028	0.0006
PCM002-10*	0.9384	15	2.2	4.14E+00	1.0306	0.0006
NSE55T5-09	0.937	2.8	11.5	3.88E+01	1.0023	0.0005
BNWL2129T4-01	0.9005	7.13	10.95	6.13E+00	1.0184	0.0006
BNWL2129T4-02	0.8909	7.64	10.89	4.51E+00	1.0178	0.0006
BNWL2129T4-04	0.8888	7.51	10.9	5.08E+00	1.0182	0.0005
BNWL2129T4-16	0.8885	7.37	10.92	5.24E+00	1.0178	0.0006
BNWL2129T4-15	0.8867	7.51	10.9	5.08E+00	1.0161	0.0005
BNWL2129T4-07	0.8856	7.57	10.89	4.91E+00	1.0165	0.0005
BNWL2129T4-09	0.8855	7.39	10.92	5.78E+00	1.0187	0.0006
BNWL2129T4-17	0.8844	7.68	10.88	4.28E+00	1.0172	0.0005
PU-15-1	0.8787	2.86	11.5	1.51E+01	0.9811	0.0003
PCM002-13*	0.8774	15	2.2	5.46E+00	1.0256	0.0006
BNWL2129T4-19	0.8724	7.79	10.87	4.05E+00	1.0181	0.0006
BNWL2129T4-12	0.8699	8.09	10.83	3.84E+00	1.02	0.0005
BNWL2129T4-10	0.8617	7.72	10.88	5.24E+00	1.0159	0.0006
BNWL2129T4-03	0.8602	8.08	10.83	3.44E+00	1.018	0.0007
BNWL2129T4-18	0.8581	7.91	10.85	3.58E+00	1.0171	0.0005
BNWL2129T4-05	0.8476	8.29	10.8	3.22E+00	1.0183	0.0006
BNWL2129T4-08	0.8292	8.71	10.75	2.40E+00	1.0186	0.0005
BNWL2129T4-11	0.8204	8.52	10.77	3.48E+00	1.0166	0.0005
BNWL2129T4-13	0.8192	8.79	10.74	2.47E+00	1.0214	0.0007
PCM001-05*	0.8181	49.6	18.35	1.54E+00	1.0087	0.0007
PCM002-05*	0.8178	0.04	18.35	1.87E+03	1.0171	0.0006
PCI001-01	0.8158	0.37	5.3	3.08E+02	0.9988	0.0001
BNWL2129T4-06	0.8074	8.81	10.74	2.24E+00	1.018	0.0005

*Benchmark experiment identified by DCS as applicable to AOA 3.

Table 8. Experimental configurations with c_k coefficients ≥ 0.8 for AOA 3-3

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
PCM001-02*	0.9647	5	11.46	1.73E+03	1.0198	0.0007
PCM002-06*	0.9537	5	11.46	9.25E+01	1.0234	0.0006
PCM002-09*	0.9486	5	11.46	5.68E+01	1.0218	0.0005
PCM002-08*	0.9483	5	11.46	6.80E+01	1.0212	0.0006
PCM002-07*	0.9339	5	11.46	8.49E+01	1.022	0.0006
PCM002-05*	0.9263	0.04	18.35	1.87E+03	1.0171	0.0006
PCM002-03*	0.9152	0.04	18.35	3.51E+03	1.0262	0.0006
PCM002-04*	0.9123	0.04	18.35	2.57E+03	1.0197	0.0006
PCM002-01*	0.908	0.04	18.35	4.92E+03	1.0322	0.0007
PCM002-02*	0.8954	0.04	18.35	4.21E+03	1.0308	0.0006
PMF016-06*	0.885	0	5.97	7.78E+03	1.0003	0.0007
PCM001-04	0.881	15	8.06	3.95E+01	0.9878	0.0007
PMF016-01*	0.8772	0	5.97	1.17E+04	1.0118	0.0006
PMF016-02*	0.8764	0	5.97	8.61E+03	1.0003	0.0006
PMF016-04*	0.8761	0	5.97	8.01E+03	0.9982	0.0007
PU-29-1	0.8755	2.77	11.5	4.14E+01	0.9941	0.0003
PU-29-2	0.8752	2.77	11.5	4.03E+01	0.9931	0.0005
PU-29-3	0.8748	2.77	11.5	4.07E+01	1.0022	0.0005
NSE55T5-01	0.8744	2.8	11.5	3.97E+01	1.0058	0.0005
PU-29-4	0.8744	2.77	11.5	3.78E+01	0.9932	0.0004
PU-29-5	0.874	2.77	11.5	3.77E+01	0.9937	0.0003
NSE55T5-05	0.8737	2.8	11.5	4.03E+01	1.002	0.0005
NSE55T5-07	0.8737	2.8	11.5	4.39E+01	1.0042	0.0005
NSE55T5-08	0.8736	2.8	11.5	3.93E+01	1.0026	0.0006
PCM001-03	0.8736	15	2.2	3.26E+01	1.0168	0.0008
PMF037-15	0.8729	0	5.97	1.82E+04	0.9985	0.0005
NSE55T5-02	0.8728	2.8	11.5	3.97E+01	1.0028	0.0005
NSE55T5-10	0.8728	2.8	11.5	3.85E+01	1.0036	0.0004
PU-29-8	0.8728	2.77	11.5	3.44E+01	0.9951	0.0005
PU-29-7	0.8727	2.77	11.5	3.48E+01	0.9944	0.0005
NSE55T5-06	0.8726	2.8	11.5	4.14E+01	1.0045	0.0005

Table 8 (continued)

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
PU-29-6	0.8723	2.77	11.5	3.67E+01	0.9931	0.0003
NSE55T5-04	0.872	2.8	11.5	4.10E+01	1.0048	0.0005
NSE55T5-03	0.8717	2.8	11.5	4.00E+01	1.0049	0.0005
PU-29-9	0.8716	2.77	11.5	3.46E+01	0.9987	0.0005
PMF016-05*	0.871	0	5.97	7.93E+03	0.9965	0.0006
NSE55T5-09	0.8696	2.8	11.5	3.88E+01	1.0023	0.0005
PMF037-07*	0.8685	0	5.97	3.30E+04	0.9984	0.0006
PMF037-12*	0.8685	0	5.97	2.35E+04	1.0009	0.0006
PMF016-03*	0.8665	0	5.97	8.34E+03	0.9995	0.0007
PMF037-05*	0.8664	0	5.97	5.12E+04	0.9977	0.0006
PMF017-05*	0.8639	0	5.97	9.39E+04	1.002	0.0006
PMF037-16	0.8622	0	5.97	2.84E+04	0.9996	0.0006
PMF037-10*	0.8596	0	5.97	2.61E+04	0.9993	0.0006
PCM002-21*	0.8495	15	2.2	6.64E+00	1.0101	0.0006
PCM002-20*	0.8489	15	2.2	6.65E+00	1.0087	0.0005
PCM002-22*	0.8483	15	2.2	6.45E+00	1.0143	0.0007
PCM002-18*	0.8471	15	2.2	6.19E+00	1.0102	0.0006
PCM002-19*	0.8464	15	2.2	6.47E+00	1.0088	0.0006
PCM002-17*	0.8393	15	2.2	4.93E+00	1.0073	0.0007
PMF037-01*	0.8379	0	5.97	1.48E+05	0.9973	0.0006
PCM002-14*	0.8378	15	2.2	5.60E+00	1.0295	0.0006
PCM002-15*	0.8375	15	2.2	5.56E+00	1.0283	0.0006
PCM002-16*	0.8358	15	2.2	5.15E+00	1.0235	0.0007
PCM002-12*	0.8331	15	2.2	5.13E+00	1.0273	0.0006
PMF017-03*	0.8328	0	5.97	2.30E+05	0.994	0.0008
PCM002-11*	0.8293	15	2.2	4.55E+00	1.028	0.0006
PCM002-10*	0.829	15	2.2	4.14E+00	1.0306	0.0006
PMF017-04	0.8244	0	5.97	4.58E+05	0.991	0.0006
PMF017-02*	0.821	0	5.97	4.05E+05	0.9932	0.0007
BNWL2129T4-01	0.8073	7.13	10.95	6.13E+00	1.0184	0.0006

*Benchmark experiment identified by DCS as applicable to AOA 3.

6.2. AOA 4 – MOX POWDERS

The S/U analysis of the applications submitted by DCS as representative of AOA 4 has revealed that numerous experimental benchmarks exceed the 0.8 criterion for c_k for three of the four critical design systems. For the fourth application, several benchmarks exhibit a c_k value that approaches this criterion for the critical configuration. For reduced mass cases using the same materials as the fourth design system, numerous benchmarks exceed the c_k criterion. Some calculated characteristics of these design systems are presented in Table 9.

Table 9. Calculated characteristics of design systems from AOA 4

Application	H/(U + Pu)	EALF (eV)	k_{eff}
AOA 4-1	1.58	127.0	1.002
AOA 4-2	1.58	3751	0.9989
AOA 4-3	1.58	27.75	1.000
AOA 4-4	0.3031	2355	0.9993
AOA 4-4-P163	0.3031	1214	0.935
AOA 4-4-P40	0.3031	367.8	0.812
AOA 4-4-P8	0.3031	86.36	0.643

Of the 318 benchmark experiments examined in this evaluation, 67 were found to exceed the c_k criterion for at least one of the design systems analyzed. For application AOA 4-1, 60 experimental benchmarks exceed the 0.8 criterion for c_k. Of these, 48 exceed a c_k value of 0.9, with 17 even exceeding 0.98, exhibiting a very strong correlation to the design system. Of the 60 experiments with a c_k of 0.8 or greater, 39 benchmarks were MOX and 21 were plutonium fueled. These results are shown in Table 10.

For application AOA 4-2, 54 benchmarks exceed the 0.8 criterion for c_k. Of these, 20 values exceed 0.9. Of the 54 experiments with c_k values exceeding 0.8, 34 are MOX and the remaining 20 are plutonium fueled. These results are shown in Table 11. Note that the matching systems exhibited EALF values of approximately 40 eV, where the EALF of this application is nearly 4000 eV. Thus, the S/U methods have identified applicable experiments where traditional techniques might not. A nuclide-reaction-specific analysis is presented in Sect. 6.2.1 to provide further information as to why the S/U analysis identifies these experiments as applicable to AOA 4-2.

For application AOA 4-3, 45 MOX benchmarks exhibit c_k values in excess of 0.8. One of these values exceeds 0.9, and no plutonium experiments have values exceeding 0.8. These results are shown in Table 12.

For application AOA 4-4, no benchmarks exceed the c_k criterion of 0.8. However, the values for 20 systems exceed 0.73, with two of these values exceeding 0.74. These results are

shown in Table 13. Each of these 20 benchmarks is a MOX system. It is noteworthy that this application system exhibits an EALF of 2355 eV, and no existing MOX benchmark presented here exhibits an EALF of this magnitude. However, AOA 4-2 exhibited an EALF even greater than that for AOA 4-4 and numerous experiments met the 0.8 criterion for AOA 4.2. This seemingly contradictory issue is further explored in Sect. 6.2.2.

For the reduced mass configurations of the material from AOA 4-4, the results are improved with decreasing mass. For the 163 kg Pu case, AOA 4-4-P163, no benchmarks exceed the 0.8 criterion for c_k. However, 28 exhibit a c_k of 0.7 or higher, with 20 of these exceeding 0.76. Of these experiments, 22 are MOX and the remaining six are plutonium fueled. These results are shown in Table 14. For the 40 kg Pu case, AOA 4-4-P40, 20 benchmarks exceed the 0.8 criterion for c_k. All of these benchmarks consist of MOX fuel. These results are shown in Table 15. For the 8 kg Pu case, AOA 4-4-P8, 46 benchmarks exceed the 0.8 criterion for c_k. Of these experiments, 38 are MOX and the remaining eight are plutonium fueled. These results are shown in Table 16. A nuclide-reaction-specific analysis is presented in Sect. 6.2.2 to provide further details on these systems.

Of the 14 benchmarks identified by DCS for the validation of AOA 4, the S/U methods have identified 10 for AOA 4-1, 10 for AOA 4-2, 14 for AOA 4-3 and none for AOA 4-4. However, of the 20 benchmarks exceeding 0.73 for the critical configuration of AOA 4-4, 10 were identified by DCS. These same 10 experiments exceeded the 0.8 criterion for two of the reduced mass cases of AOA 4-4. The experiments identified by DCS are noted in Tables 10–16.

Table 10. Experimental configurations with c_k coefficients ≥ 0.8 for AOA 4-1

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
PU-29-2*	0.9837	2.77	11.5	4.03E+01	0.9931	0.0005
PU-29-1*	0.9836	2.77	11.5	4.14E+01	0.9941	0.0003
NSE55T5-07	0.9833	2.8	11.5	4.39E+01	1.0042	0.0005
PU-29-3*	0.9829	2.77	11.5	4.07E+01	1.0022	0.0005
PU-29-4*	0.9824	2.77	11.5	3.78E+01	0.9932	0.0004
NSE55T5-10	0.9822	2.8	11.5	3.85E+01	1.0036	0.0004
PU-29-5*	0.9822	2.77	11.5	3.77E+01	0.9937	0.0003
NSE55T5-06	0.9821	2.8	11.5	4.14E+01	1.0045	0.0005
NSE55T5-01	0.9819	2.8	11.5	3.97E+01	1.0058	0.0005
NSE55T5-05	0.9817	2.8	11.5	4.03E+01	1.002	0.0005
NSE55T5-02	0.9811	2.8	11.5	3.97E+01	1.0028	0.0005
NSE55T5-08	0.9809	2.8	11.5	3.93E+01	1.0026	0.0006
PU-29-7*	0.9808	2.77	11.5	3.48E+01	0.9944	0.0005
NSE55T5-04	0.9806	2.8	11.5	4.10E+01	1.0048	0.0005
PU-29-8*	0.9805	2.77	11.5	3.44E+01	0.9951	0.0005
NSE55T5-03	0.9803	2.8	11.5	4.00E+01	1.0049	0.0005
PU-29-6*	0.9803	2.77	11.5	3.67E+01	0.9931	0.0003
PU-29-9*	0.9796	2.77	11.5	3.46E+01	0.9987	0.0005
NSE55T5-09	0.9783	2.8	11.5	3.88E+01	1.0023	0.0005
PU-15-1*	0.9493	2.86	11.5	1.51E+01	0.9811	0.0003
PCM002-06	0.9484	5	11.46	9.25E+01	1.0234	0.0006
PCM002-07	0.9470	5	11.46	8.49E+01	1.022	0.0006
PCM002-09	0.9451	5	11.46	5.68E+01	1.0218	0.0005
PCM002-08	0.9447	5	11.46	6.80E+01	1.0212	0.0006
BNWL2129T4-01	0.9367	7.13	10.95	6.13E+00	1.0184	0.0006
PCM001-04	0.9359	15	8.06	3.95E+01	0.9878	0.0007
PCM001-02	0.9329	5	11.46	1.73E+03	1.0198	0.0007
BNWL2129T4-02	0.9268	7.64	10.89	4.51E+00	1.0178	0.0006
BNWL2129T4-09	0.9261	7.39	10.92	5.78E+00	1.0187	0.0006
BNWL2129T4-04	0.9258	7.51	10.9	5.08E+00	1.0182	0.0005
PCM001-03	0.9241	15	2.2	3.26E+01	1.0168	0.0008
BNWL2129T4-16	0.9237	7.37	10.92	5.24E+00	1.0178	0.0006

Table 10 (continued)

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
BNWL2129T4-07	0.9230	7.57	10.89	4.91E+00	1.0165	0.0005
BNWL2129T4-15	0.9224	7.51	10.9	5.08E+00	1.0161	0.0005
PCM002-21	0.9198	15	2.2	6.64E+00	1.0101	0.0006
BNWL2129T4-17	0.9193	7.68	10.88	4.28E+00	1.0172	0.0005
PCM002-22	0.9182	15	2.2	6.45E+00	1.0143	0.0007
PCM002-20	0.9176	15	2.2	6.65E+00	1.0087	0.0005
PCM002-18	0.9164	15	2.2	6.19E+00	1.0102	0.0006
PCM002-19	0.9149	15	2.2	6.47E+00	1.0088	0.0006
PCM002-17	0.9108	15	2.2	4.93E+00	1.0073	0.0007
BNWL2129T4-19	0.9068	7.79	10.87	4.05E+00	1.0181	0.0006
BNWL2129T4-12	0.9054	8.09	10.83	3.84E+00	1.02	0.0005
PCM002-15	0.9053	15	2.2	5.56E+00	1.0283	0.0006
PCM002-14	0.9045	15	2.2	5.60E+00	1.0295	0.0006
BNWL2129T4-10	0.9043	7.72	10.88	5.24E+00	1.0159	0.0006
PCM002-16	0.9023	15	2.2	5.15E+00	1.0235	0.0007
PCM002-12	0.9005	15	2.2	5.13E+00	1.0273	0.0006
PCM002-10	0.8984	15	2.2	4.14E+00	1.0306	0.0006
PCM002-11	0.8977	15	2.2	4.55E+00	1.028	0.0006
BNWL2129T4-03	0.8947	8.08	10.83	3.44E+00	1.018	0.0007
BNWL2129T4-18	0.8921	7.91	10.85	3.58E+00	1.0171	0.0005
BNWL2129T4-05	0.8824	8.29	10.8	3.22E+00	1.0183	0.0006
BNWL2129T4-11	0.8648	8.52	10.77	3.48E+00	1.0166	0.0005
BNWL2129T4-08	0.8640	8.71	10.75	2.40E+00	1.0186	0.0005
BNWL2129T4-13	0.8549	8.79	10.74	2.47E+00	1.0214	0.0007
PCI001-01	0.8493	0.37	5.3	3.08E+02	0.9988	0.0001
PCM002-13	0.8454	15	2.2	5.46E+00	1.0256	0.0006
BNWL2129T4-06	0.8410	8.81	10.74	2.24E+00	1.018	0.0005
MCT001-01	0.8112	3.3346	11.5414	1.61E-03	1.0022	0.0005

*Benchmark experiment identified by DCS as applicable to AOA 4.

Table 11. Experimental configurations with c_k coefficients ≥ 0.8 for AOA 4-2

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
NSE55T5-07	0.9371	2.8	11.5	4.39E+01	1.0042	0.0005
NSE55T5-04	0.9356	2.8	11.5	4.10E+01	1.0048	0.0005
NSE55T5-06	0.9354	2.8	11.5	4.14E+01	1.0045	0.0005
NSE55T5-05	0.9350	2.8	11.5	4.03E+01	1.002	0.0005
NSE55T5-01	0.9345	2.8	11.5	3.97E+01	1.0058	0.0005
PU-29-3*	0.9342	2.77	11.5	4.07E+01	1.0022	0.0005
NSE55T5-03	0.9341	2.8	11.5	4.00E+01	1.0049	0.0005
PU-29-1*	0.9340	2.77	11.5	4.14E+01	0.9941	0.0003
PU-29-2*	0.9339	2.77	11.5	4.03E+01	0.9931	0.0005
NSE55T5-10	0.9336	2.8	11.5	3.85E+01	1.0036	0.0004
NSE55T5-02	0.9334	2.8	11.5	3.97E+01	1.0028	0.0005
NSE55T5-08	0.9334	2.8	11.5	3.93E+01	1.0026	0.0006
PU-29-4*	0.9324	2.77	11.5	3.78E+01	0.9932	0.0004
PU-29-5*	0.9322	2.77	11.5	3.77E+01	0.9937	0.0003
PU-29-8*	0.9311	2.77	11.5	3.44E+01	0.9951	0.0005
NSE55T5-09	0.9305	2.8	11.5	3.88E+01	1.0023	0.0005
PU-29-7*	0.9303	2.77	11.5	3.48E+01	0.9944	0.0005
PU-29-6*	0.9299	2.77	11.5	3.67E+01	0.9931	0.0003
PU-29-9*	0.9298	2.77	11.5	3.46E+01	0.9987	0.0005
PU-15-1*	0.9086	2.86	11.5	1.51E+01	0.9811	0.0003
PCM001-02	0.8974	5	11.46	1.73E+03	1.0198	0.0007
PCM002-07	0.8955	5	11.46	8.49E+01	1.022	0.0006
PCM002-06	0.8898	5	11.46	9.25E+01	1.0234	0.0006
PCM002-09	0.8841	5	11.46	5.68E+01	1.0218	0.0005
PCM002-08	0.8828	5	11.46	6.80E+01	1.0212	0.0006
PCM001-04	0.8784	15	8.06	3.95E+01	0.9878	0.0007
BNWL2129T4-01	0.8651	7.13	10.95	6.13E+00	1.0184	0.0006
PCM001-03	0.8615	15	2.2	3.26E+01	1.0168	0.0008
BNWL2129T4-02	0.8557	7.64	10.89	4.51E+00	1.0178	0.0006
BNWL2129T4-09	0.8543	7.39	10.92	5.78E+00	1.0187	0.0006
BNWL2129T4-04	0.8532	7.51	10.9	5.08E+00	1.0182	0.0005

Table 11 (continued)

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
BNWL2129T4-07	0.8509	7.57	10.89	4.91E+00	1.0165	0.0005
BNWL2129T4-16	0.8508	7.37	10.92	5.24E+00	1.0178	0.0006
BNWL2129T4-15	0.8505	7.51	10.9	5.08E+00	1.0161	0.0005
BNWL2129T4-17	0.8452	7.68	10.88	4.28E+00	1.0172	0.0005
PCM002-21	0.8452	15	2.2	6.64E+00	1.0101	0.0006
PCM002-22	0.8415	15	2.2	6.45E+00	1.0143	0.0007
PCM002-20	0.8403	15	2.2	6.65E+00	1.0087	0.0005
PCI001-01	0.8388	0.37	5.3	3.08E+02	0.9988	0.0001
PCM002-18	0.8387	15	2.2	6.19E+00	1.0102	0.0006
PCM002-19	0.8375	15	2.2	6.47E+00	1.0088	0.0006
BNWL2129T4-10	0.8353	7.72	10.88	5.24E+00	1.0159	0.0006
PCM002-17	0.8315	15	2.2	4.93E+00	1.0073	0.0007
BNWL2129T4-19	0.8287	7.79	10.87	4.05E+00	1.0181	0.0006
BNWL2129T4-12	0.8282	8.09	10.83	3.84E+00	1.02	0.0005
PCM002-14	0.8251	15	2.2	5.60E+00	1.0295	0.0006
PCM002-15	0.8250	15	2.2	5.56E+00	1.0283	0.0006
PCM002-16	0.8221	15	2.2	5.15E+00	1.0235	0.0007
PCM002-12	0.8203	15	2.2	5.13E+00	1.0273	0.0006
BNWL2129T4-03	0.8173	8.08	10.83	3.44E+00	1.018	0.0007
PCM002-10	0.8173	15	2.2	4.14E+00	1.0306	0.0006
PCM002-11	0.8165	15	2.2	4.55E+00	1.028	0.0006
BNWL2129T4-18	0.8131	7.91	10.85	3.58E+00	1.0171	0.0005
BNWL2129T4-05	0.8016	8.29	10.8	3.22E+00	1.0183	0.0006

*Benchmark experiment identified by DCS as applicable to AOA 4.

Table 12. Experimental configurations with c_k coefficients ≥ 0.8 for AOA 4-3

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
PU-15-1*	0.9036	2.86	11.5	1.51E+01	0.9811	0.0003
BNWL2129T4-10	0.8482	7.72	10.88	5.24E+00	1.0159	0.0006
BNWL2129T4-09	0.8468	7.39	10.92	5.78E+00	1.0187	0.0006
NSE55T5-07	0.8442	2.8	11.5	4.39E+01	1.0042	0.0005
BNWL2129T4-01	0.8441	7.13	10.95	6.13E+00	1.0184	0.0006
NSE55T5-10	0.8432	2.8	11.5	3.85E+01	1.0036	0.0004
PU-29-7*	0.8425	2.77	11.5	3.48E+01	0.9944	0.0005
NSE55T5-01	0.8423	2.8	11.5	3.97E+01	1.0058	0.0005
NSE55T5-02	0.8422	2.8	11.5	3.97E+01	1.0028	0.0005
NSE55T5-04	0.8419	2.8	11.5	4.10E+01	1.0048	0.0005
NSE55T5-05	0.8417	2.8	11.5	4.03E+01	1.002	0.0005
NSE55T5-03	0.8416	2.8	11.5	4.00E+01	1.0049	0.0005
PU-29-3*	0.8416	2.77	11.5	4.07E+01	1.0022	0.0005
PU-29-4*	0.8416	2.77	11.5	3.78E+01	0.9932	0.0004
BNWL2129T4-02	0.8414	7.64	10.89	4.51E+00	1.0178	0.0006
PU-29-8*	0.8414	2.77	11.5	3.44E+01	0.9951	0.0005
PU-29-9*	0.8413	2.77	11.5	3.46E+01	0.9987	0.0005
PU-29-1*	0.8408	2.77	11.5	4.14E+01	0.9941	0.0003
BNWL2129T4-11	0.8407	8.52	10.77	3.48E+00	1.0166	0.0005
BNWL2129T4-16	0.8405	7.37	10.92	5.24E+00	1.0178	0.0006
NSE55T5-06	0.8405	2.8	11.5	4.14E+01	1.0045	0.0005
PU-29-5*	0.8405	2.77	11.5	3.77E+01	0.9937	0.0003
PU-29-6*	0.8405	2.77	11.5	3.67E+01	0.9931	0.0003
PU-29-2*	0.8404	2.77	11.5	4.03E+01	0.9931	0.0005
BNWL2129T4-04	0.8402	7.51	10.9	5.08E+00	1.0182	0.0005
BNWL2129T4-15	0.8402	7.51	10.9	5.08E+00	1.0161	0.0005
NSE55T5-08	0.8399	2.8	11.5	3.93E+01	1.0026	0.0006
BNWL2129T4-07	0.8391	7.57	10.89	4.91E+00	1.0165	0.0005
BNWL2129T4-17	0.8377	7.68	10.88	4.28E+00	1.0172	0.0005
NSE55T5-09	0.8359	2.8	11.5	3.88E+01	1.0023	0.0005
BNWL2129T4-19	0.8347	7.79	10.87	4.05E+00	1.0181	0.0006

Table 12 (continued)

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
BNWL2129T4-12	0.8340	8.09	10.83	3.84E+00	1.02	0.0005
BNWL2129T4-03	0.8313	8.08	10.83	3.44E+00	1.018	0.0007
BNWL2129T4-18	0.8283	7.91	10.85	3.58E+00	1.0171	0.0005
BNWL2129T4-05	0.8244	8.29	10.8	3.22E+00	1.0183	0.0006
MCT002-02	0.8233	1.1946	7.7593	7.73E-01	0.9958	0.0006
MCT009-01	0.8189	1.4103	7.8651	5.52E-01	0.9945	0.0005
BNWL2129T4-08	0.8181	8.71	10.75	2.40E+00	1.0186	0.0005
PU-8-3*	0.8180	7.33	11.5	6.38E-01	1.0059	0.0006
PU-8-4*	0.8180	7.33	11.5	6.30E-01	1.0053	0.0006
PU-8-2*	0.8179	7.33	11.5	6.41E-01	1.0036	0.0005
PU-8-1*	0.8178	7.33	11.5	6.45E-01	1.005	0.0006
BNWL2129T4-13	0.8104	8.79	10.74	2.47E+00	1.0214	0.0007
BNWL2129T4-06	0.8055	8.81	10.74	2.24E+00	1.018	0.0005
MCT002-01	0.8032	1.1946	7.7593	5.79E-01	0.9934	0.0006

*Benchmark experiment identified by DCS as applicable to AOA 4

Table 13. Experimental configurations with c_k coefficients ≥ 0.7 for AOA 4-4

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
NSE55T5-04	0.7420	2.8	11.5	4.10E+01	1.0048	0.0005
PU-15-1*	0.7420	2.86	11.5	1.51E+01	0.9811	0.0003
NSE55T5-03	0.7388	2.8	11.5	4.00E+01	1.0049	0.0005
NSE55T5-05	0.7372	2.8	11.5	4.03E+01	1.002	0.0005
NSE55T5-07	0.7363	2.8	11.5	4.39E+01	1.0042	0.0005
NSE55T5-01	0.7358	2.8	11.5	3.97E+01	1.0058	0.0005
NSE55T5-08	0.7357	2.8	11.5	3.93E+01	1.0026	0.0006
NSE55T5-06	0.7354	2.8	11.5	4.14E+01	1.0045	0.0005
NSE55T5-02	0.7349	2.8	11.5	3.97E+01	1.0028	0.0005
NSE55T5-09	0.7332	2.8	11.5	3.88E+01	1.0023	0.0005
PU-29-3*	0.7330	2.77	11.5	4.07E+01	1.0022	0.0005
PU-29-8*	0.7330	2.77	11.5	3.44E+01	0.9951	0.0005
PU-29-9*	0.7325	2.77	11.5	3.46E+01	0.9987	0.0005
NSE55T5-10	0.7316	2.8	11.5	3.85E+01	1.0036	0.0004
PU-29-6*	0.7311	2.77	11.5	3.67E+01	0.9931	0.0003
PU-29-4*	0.7306	2.77	11.5	3.78E+01	0.9932	0.0004
PU-29-5*	0.7306	2.77	11.5	3.77E+01	0.9937	0.0003
PU-29-7*	0.7305	2.77	11.5	3.48E+01	0.9944	0.0005
PU-29-1*	0.7303	2.77	11.5	4.14E+01	0.9941	0.0003
PU-29-2*	0.7293	2.77	11.5	4.03E+01	0.9931	0.0005

*Benchmark experiment identified by DCS as applicable to AOA 4.

Table 14. Experimental configurations with c_k coefficients ≥ 0.7 for AOA 4-4-P163

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
NSE55T5-04	0.7718	2.8	11.5	4.10E+01	1.0048	0.0005
PU-15-1*	0.7714	2.86	11.5	1.51E+01	0.9811	0.0003
NSE55T5-03	0.7689	2.8	11.5	4.00E+01	1.0049	0.0005
NSE55T5-05	0.7676	2.8	11.5	4.03E+01	1.002	0.0005
NSE55T5-07	0.7663	2.8	11.5	4.39E+01	1.0042	0.0005
NSE55T5-01	0.7662	2.8	11.5	3.97E+01	1.0058	0.0005
NSE55T5-08	0.7661	2.8	11.5	3.93E+01	1.0026	0.0006
NSE55T5-06	0.7659	2.8	11.5	4.14E+01	1.0045	0.0005
NSE55T5-02	0.7654	2.8	11.5	3.97E+01	1.0028	0.0005
NSE55T5-09	0.7643	2.8	11.5	3.88E+01	1.0023	0.0005
PU-29-3*	0.7639	2.77	11.5	4.07E+01	1.0022	0.0005
PU-29-8*	0.7638	2.77	11.5	3.44E+01	0.9951	0.0005
PU-29-9*	0.7633	2.77	11.5	3.46E+01	0.9987	0.0005
NSE55T5-10	0.7622	2.8	11.5	3.85E+01	1.0036	0.0004
PU-29-6*	0.7622	2.77	11.5	3.67E+01	0.9931	0.0003
PU-29-5*	0.7617	2.77	11.5	3.77E+01	0.9937	0.0003
PU-29-4*	0.7616	2.77	11.5	3.78E+01	0.9932	0.0004
PU-29-1*	0.7615	2.77	11.5	4.14E+01	0.9941	0.0003
PU-29-7*	0.7615	2.77	11.5	3.48E+01	0.9944	0.0005
PU-29-2*	0.7605	2.77	11.5	4.03E+01	0.9931	0.0005
PCM002-09	0.7132	5	11.46	5.68E+01	1.0218	0.0005
PCM001-02	0.7114	5	11.46	1.73E+03	1.0198	0.0007
PCM002-06	0.7082	5	11.46	9.25E+01	1.0234	0.0006
BNWL2129T4-01	0.7017	7.13	10.95	6.13E+00	1.0184	0.0006
PCM002-07	0.7016	5	11.46	8.49E+01	1.022	0.0006
PCM002-08	0.7008	5	11.46	6.80E+01	1.0212	0.0006
BNWL2129T4-02	0.7006	7.64	10.89	4.51E+00	1.0178	0.0006
PCI001-01	0.7001	0.37	5.3	3.08E+02	0.9988	0.0001

*Benchmark experiment identified by DCS as applicable to AOA 4.

Table 15. Experimental configurations with c_k coefficients ≥ 0.8 for AOA 4-4-P40

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
PU-15-1*	0.8323	2.86	11.5	1.51E+01	0.9811	0.0003
NSE55T5-04	0.8320	2.8	11.5	4.10E+01	1.0048	0.0005
NSE55T5-03	0.8300	2.8	11.5	4.00E+01	1.0049	0.0005
NSE55T5-05	0.8291	2.8	11.5	4.03E+01	1.002	0.0005
NSE55T5-01	0.8278	2.8	11.5	3.97E+01	1.0058	0.0005
NSE55T5-08	0.8278	2.8	11.5	3.93E+01	1.0026	0.0006
NSE55T5-02	0.8276	2.8	11.5	3.97E+01	1.0028	0.0005
NSE55T5-09	0.8275	2.8	11.5	3.88E+01	1.0023	0.0005
NSE55T5-06	0.8274	2.8	11.5	4.14E+01	1.0045	0.0005
PU-29-8*	0.8270	2.77	11.5	3.44E+01	0.9951	0.0005
NSE55T5-07	0.8265	2.8	11.5	4.39E+01	1.0042	0.0005
PU-29-3*	0.8265	2.77	11.5	4.07E+01	1.0022	0.0005
PU-29-9*	0.8265	2.77	11.5	3.46E+01	0.9987	0.0005
PU-29-6*	0.8261	2.77	11.5	3.67E+01	0.9931	0.0003
PU-29-5*	0.8253	2.77	11.5	3.77E+01	0.9937	0.0003
PU-29-4*	0.8250	2.77	11.5	3.78E+01	0.9932	0.0004
PU-29-7*	0.8250	2.77	11.5	3.48E+01	0.9944	0.0005
PU-29-1*	0.8249	2.77	11.5	4.14E+01	0.9941	0.0003
NSE55T5-10	0.8244	2.8	11.5	3.85E+01	1.0036	0.0004
PU-29-2*	0.8242	2.77	11.5	4.03E+01	0.9931	0.0005

*Benchmark experiment identified by DCS as applicable to AOA 4.

Table 16. Experimental configurations with c_k coefficients ≥ 0.8 for AOA 4-4-P8

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
PU-15-1*	0.8915	2.86	11.5	1.51E+01	0.9811	0.0003
PU-29-6*	0.8883	2.77	11.5	3.67E+01	0.9931	0.0003
PU-29-8*	0.8878	2.77	11.5	3.44E+01	0.9951	0.0005
PU-29-9*	0.8877	2.77	11.5	3.46E+01	0.9987	0.0005
NSE55T5-09	0.8876	2.8	11.5	3.88E+01	1.0023	0.0005
PU-29-5*	0.8867	2.77	11.5	3.77E+01	0.9937	0.0003
PU-29-7*	0.8867	2.77	11.5	3.48E+01	0.9944	0.0005
NSE55T5-04	0.8863	2.8	11.5	4.10E+01	1.0048	0.0005
NSE55T5-03	0.8862	2.8	11.5	4.00E+01	1.0049	0.0005
NSE55T5-02	0.8861	2.8	11.5	3.97E+01	1.0028	0.0005
NSE55T5-05	0.8861	2.8	11.5	4.03E+01	1.002	0.0005
PU-29-4*	0.8860	2.77	11.5	3.78E+01	0.9932	0.0004
PU-29-3*	0.8858	2.77	11.5	4.07E+01	1.0022	0.0005
PU-29-1*	0.8856	2.77	11.5	4.14E+01	0.9941	0.0003
NSE55T5-08	0.8855	2.8	11.5	3.93E+01	1.0026	0.0006
PU-29-2*	0.8852	2.77	11.5	4.03E+01	0.9931	0.0005
NSE55T5-01	0.8851	2.8	11.5	3.97E+01	1.0058	0.0005
NSE55T5-06	0.8841	2.8	11.5	4.14E+01	1.0045	0.0005
NSE55T5-10	0.8831	2.8	11.5	3.85E+01	1.0036	0.0004
NSE55T5-07	0.8810	2.8	11.5	4.39E+01	1.0042	0.0005
BNWL2129T4-10	0.8763	7.72	10.88	5.24E+00	1.0159	0.0006
BNWL2129T4-09	0.8760	7.39	10.92	5.78E+00	1.0187	0.0006
BNWL2129T4-01	0.8752	7.13	10.95	6.13E+00	1.0184	0.0006
BNWL2129T4-07	0.8748	7.57	10.89	4.91E+00	1.0165	0.0005
BNWL2129T4-15	0.8742	7.51	10.9	5.08E+00	1.0161	0.0005
BNWL2129T4-02	0.8740	7.64	10.89	4.51E+00	1.0178	0.0006
BNWL2129T4-04	0.8738	7.51	10.9	5.08E+00	1.0182	0.0005
BNWL2129T4-16	0.8724	7.37	10.92	5.24E+00	1.0178	0.0006
BNWL2129T4-17	0.8706	7.68	10.88	4.28E+00	1.0172	0.0005
BNWL2129T4-12	0.8639	8.09	10.83	3.84E+00	1.02	0.0005
BNWL2129T4-11	0.8612	8.52	10.77	3.48E+00	1.0166	0.0005

Table 16 (continued)

Experiment	c_k	H/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
BNWL2129T4-19	0.8612	7.79	10.87	4.05E+00	1.0181	0.0006
BNWL2129T4-03	0.8582	8.08	10.83	3.44E+00	1.018	0.0007
BNWL2129T4-18	0.8578	7.91	10.85	3.58E+00	1.0171	0.0005
BNWL2129T4-05	0.8528	8.29	10.8	3.22E+00	1.0183	0.0006
BNWL2129T4-08	0.8450	8.71	10.75	2.40E+00	1.0186	0.0005
BNWL2129T4-13	0.8413	8.79	10.74	2.47E+00	1.0214	0.0007
PCM002-09	0.8406	5	11.46	5.68E+01	1.0218	0.0005
BNWL2129T4-06	0.8281	8.81	10.74	2.24E+00	1.018	0.0005
PCM002-06	0.8217	5	11.46	9.25E+01	1.0234	0.0006
PCM002-08	0.8209	5	11.46	6.80E+01	1.0212	0.0006
PCM002-13	0.8029	15	2.2	5.46E+00	1.0256	0.0006
PCM002-20	0.8026	15	2.2	6.65E+00	1.0087	0.0005
PCM002-18	0.8025	15	2.2	6.19E+00	1.0102	0.0006
PCM002-17	0.8022	15	2.2	4.93E+00	1.0073	0.0007
PCM002-22	0.8010	15	2.2	6.45E+00	1.0143	0.0007

*Benchmark experiment identified by DCS as applicable to AOA 4.

6.2.1. Nuclide-Reaction-Specific Analysis of AOA 4-2

To gain more understanding of the physics that lead to the high-valued correlation coefficients for design system AOA 4-2 where traditional trending methods might indicate less applicability, a nuclide-reaction-specific sensitivity analysis was performed for two selected benchmark experiments. The two selected experiments are NSE55T4-01 and NSE55T5-04, which exhibit c_k values with AOA 4-2 of 0.5273 and 0.9256, respectively. Pertinent data for each of these systems is shown in Table 17. Note that the EALF values indicate that the average fission distribution is quite different between the design application and the two benchmarks. However, the H/(Pu + U) and Pu/(Pu + U) ratios are comparable, especially for NSE55T5-04.

Table 17. Properties of systems considered for nuclide-reaction-specific analysis of AOA 4-2

	AOA 4-2	NSE55T4-01	NSE55T5-04
c_k value with AOA 4-2	1.0	0.5273	0.9356
H/(Pu + U)	1.58	30.6	2.8
Pu/(Pu + U)	0.219	0.146	0.303
Wt % ^{240}Pu	4	7.97	11.5
EALF (eV)	3751	0.143	41.0

The $T(c_k)$ values were computed for important reactions for each of these experiments in relation to AOA 4-2. Recall that a $T(c_k)$ value of 1.0 indicates that for the particular nuclide-reaction pair considered, the benchmark exhibits the same amount of shared variance as the application. Previous studies have used a criterion of 0.95 for T values to indicate coverage of an application by a benchmark.[5] The contribution of each reaction to the c_k value for the system is related to the magnitude of the sensitivity coefficient for the application. Thus, a system with several high-sensitivity reactions that also have high $T(c_k)$ values would produce a high c_k value. The sensitivity coefficients and $T(c_k)$ values for AOA 4-2 are presented in Table 18.

Table 18. Nuclide-reaction-specific sensitivity data for AOA 4-2 with $T(c_k)$ values
for benchmarks NSE55T4-01 and NSE55T5-04

	Sensitivity coefficient	$T(c_k)$	
		NSE55T4-01	NSE55T5-04
^{1}H scatter	0.1463	3.1860	0.9246
^{239}Pu fission	0.4690	0.1640	0.9525
^{239}Pu capture	−0.1722	0.3105	0.9671
^{238}U fission	0.09601	0.0794	0.3550
^{238}U capture	−0.1834	0.3465	0.4850
^{238}U scatter	0.09838	0.0678	0.1743

Examination of the data in Table 18 provides insight as to why NSE55T5-04 exhibits a high correlation with AOA 4-2, even though the EALF values might indicate otherwise. For the reaction for which AOA 4-2 exhibits the most sensitivity, ^{239}Pu fission, NSE55T5-04 provides adequate coverage, with a $T(c_k)$ value 0.9525. Two other important reactions, ^{1}H scatter and ^{239}Pu capture are also well covered. Although the ^{238}U reactions are not covered as well, the overall coverage for important nuclides and reactions is adequate to produce a high c_k value. In contrast, the $T(c_k)$ values for NSE55T4-01 show that it only provides adequate coverage for ^{1}H scatter. The coverage for ^{239}Pu fission is quite poor, and thus, the c_k value produced for this benchmark is much lower.

The properties of NSE55T5-04 that are most likely responsible for the high correlation coefficient with AOA 4-2, even though the EALF values of the systems differ by two orders of magnitude, are the high Pu/(Pu + U) ratio and the low H/(Pu + U) ratio. Even though the EALF values indicate that the average fission distributions of the two systems are quite different, the benchmark is fueled with enough ^{239}Pu that the sensitivity of k_{eff} to ^{239}Pu fission has a large enough magnitude at fast energies to provide a high correlation with the design application. The energy-dependent ^{239}Pu fission sensitivity profiles are presented in Fig. 1, which illustrates that, although the sensitivity of NSE55T5-04 is more pronounced in the thermal region, it is still comparable to that of AOA 4-2 though intermediate and fast energies. The highly correlated NSE55T5-04 is contrasted by the poorly correlated NSE55T4-01, whose ^{239}Pu fission sensitivity profile demonstrates the dominance of thermal fission in this system.
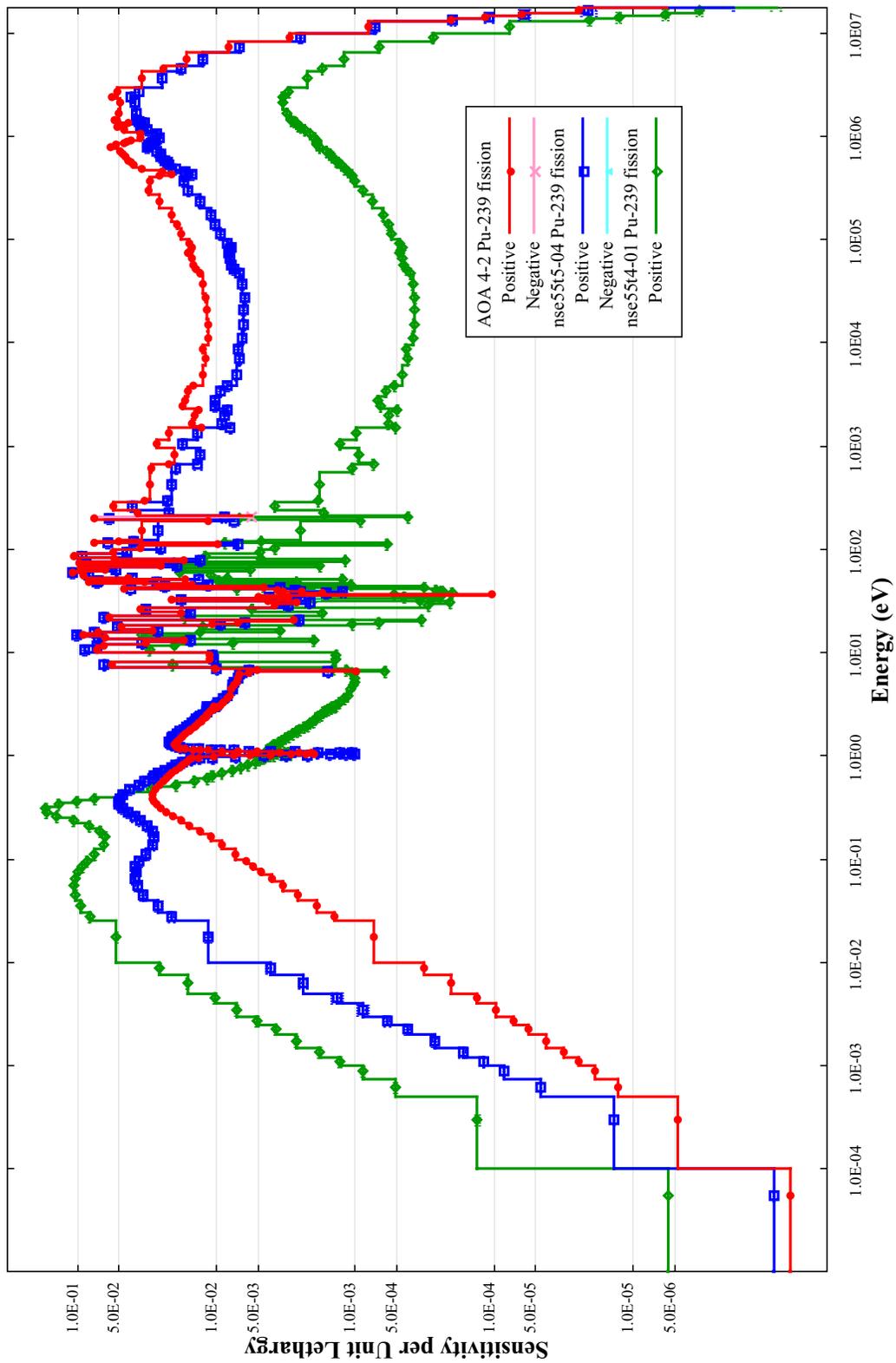
Fig. 1. Energy-dependent-sensitivity profiles for ^{239}Pu fission for AOA 4-2, Experiment 4 from Table 5 of NSE55, and Experiment 1 from Table 4 of NSE55.

6.2.2.   Analysis of Mass Variations for AOA 4-4

The variation in the correlation coefficient with system mass for the four cases of AOA 4-4 was further investigated using the nuclide-reaction-specific S/U tools. As noted in Sect. 6.2, the S/U methods found that no benchmark experiments met the 0.8 criterion for c_k for the critical configuration, but the correlation coefficients are improved as the mass of the system is reduced. Although the previous section explained how a system with an EALF of nearly 4000 eV could be highly correlated to systems with much lower average spectra, this argument does not apply to the critical configuration of AOA 4-4. The EALF for this system is 2355 eV, but the energy-dependent profiles exhibit a higher sensitivity in the fast range for AOA 4-4 than is observed for AOA 4-2. This is shown in Fig. 2. This difference in the profiles, when coupled with the cross-section-covariance data, for all nuclides in the system results in a significantly different correlation coefficient.

Table 19 presents the sensitivity coefficients for important reactions for each system with the corresponding $T(c_k)$ values generated with MOX polystyrene compact benchmark experiment PU-29-1. To further illustrate the differences among these systems, the energy-dependent-sensitivity profiles for each of these design systems and benchmark-experiment PU-29-1 are presented below. This data is presented in Fig. 3 for ^{239}Pu fission and in Fig. 4 for ^{238}U capture. Recall that PU-29-1 exhibited c_k values of 0.7303, 0.7615, 0.8249 and 0.8856 for AOA 4-4, AOA 4-4-P163, AOA 4-4-P40 and AOA 4-4-P8, respectively. An examination of the effects due to the reduction of system mass for each nuclide-reaction pair will be presented here. For ^{1}H scatter, which will mostly occur in the water reflector of this dry system, reducing the mass of fuel in the system places a higher percentage of the fuel in proximity of the reflector, and thus increases the sensitivity of the system to hydrogen in the reflector region. With its increased importance, which is greater than that observed in the benchmark experiment, the coverage of this nuclide is diminished. However, because the cross-section data for ^{1}H scatter is well known, the covariance data has a small magnitude, and its effect on the global c_k correlation coefficient is minimized. For ^{239}Pu fission, although the magnitude of the sensitivity coefficient is decreased, the $T(c_k)$ value is somewhat improved for AOA 4-4-P8 and minimally reduced for the other reduced mass cases. Fig. 3 illustrates that ^{239}Pu fission will have a positive contribution to $c_{k,}$ as the sensitivity profiles for the reduced mass cases approach that of the benchmark experiment, especially in the fast region.   A similar effect is produced for ^{239}Pu capture, although the sensitivity profiles are not shown. For ^{238}U fission, the $T(c_k)$ values are reduced as the sensitivity coefficient increases, similar to the effect seen for ^{1}H scatter. For ^{238}U capture, as the spectrum of the system is shifted towards thermal with reduced mass, the sensitivity to ^{238}U capture is reduced.   The $T(c_k)$ value is somewhat improved, but is still quite low. However, this slight improvement in $T(c_k)$, along with the reduction in the magnitude of the sensitivity coefficient, will produce a noticeable increase in c_k.   The trend of the sensitivity profiles towards that of the benchmark experiment, especially in the fast region, is shown in Fig. 4.
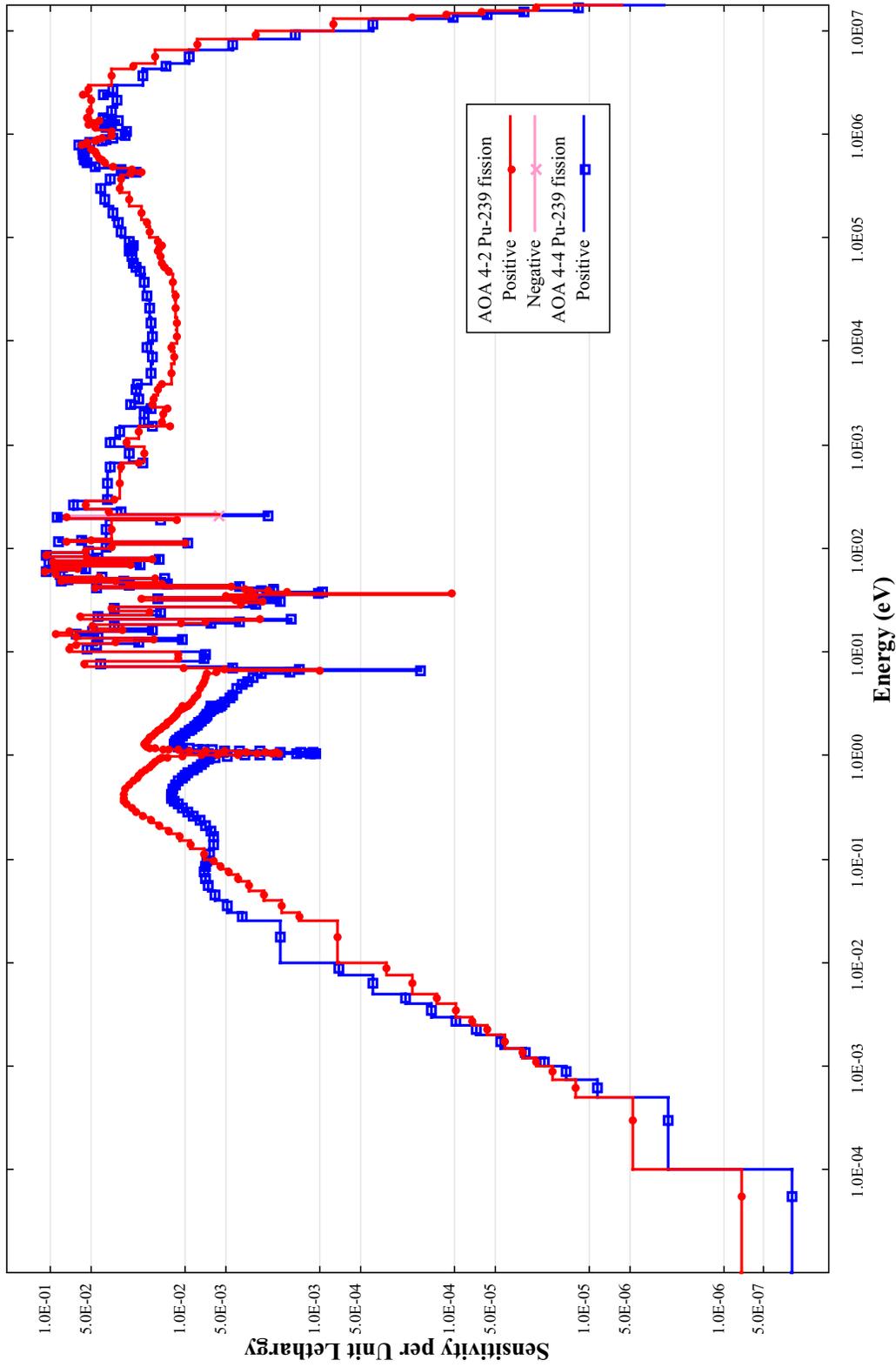
Fig. 2. Energy-dependent-sensitivity profiles for ^{239}Pu fission for AOA 4-2 and AOA 4-4.

Table 19. Nuclide-reaction-specific-sensitivity data for the various masses analyzed for AOA 4-4 with $T(c_k)$ values for benchmark PU-29-1

	AOA 4-4		AOA 4-4-P8		AOA 4-4-P40		AOA 4-4-P163	
	Sensitivity coefficient	$T(c_k)$	Sensitivity coefficient	$T(c_k)$	Sensitivity coefficient	$T(c_k)$	Sensitivity coefficient	$T(c_k)$
^{1}H scatter	0.06517	4.1363	0.2677	0.4377	0.1572	0.9477	0.09351	1.1402
^{239}Pu fission	0.4652	1.032	0.3982	1.0969	0.4333	1.0076	0.4564	1.014
^{239}Pu capture	−0.1322	1.4331	−0.1655	1.6037	−0.1464	1.5339	−0.1355	1.4568
^{238}U fission	0.1283	0.327	0.1519	0.172	0.1444	0.2255	0.1349	0.2872
^{238}U capture	−0.3020	0.3399	−0.1424	0.4859	−0.2178	0.3731	−0.2753	0.3457
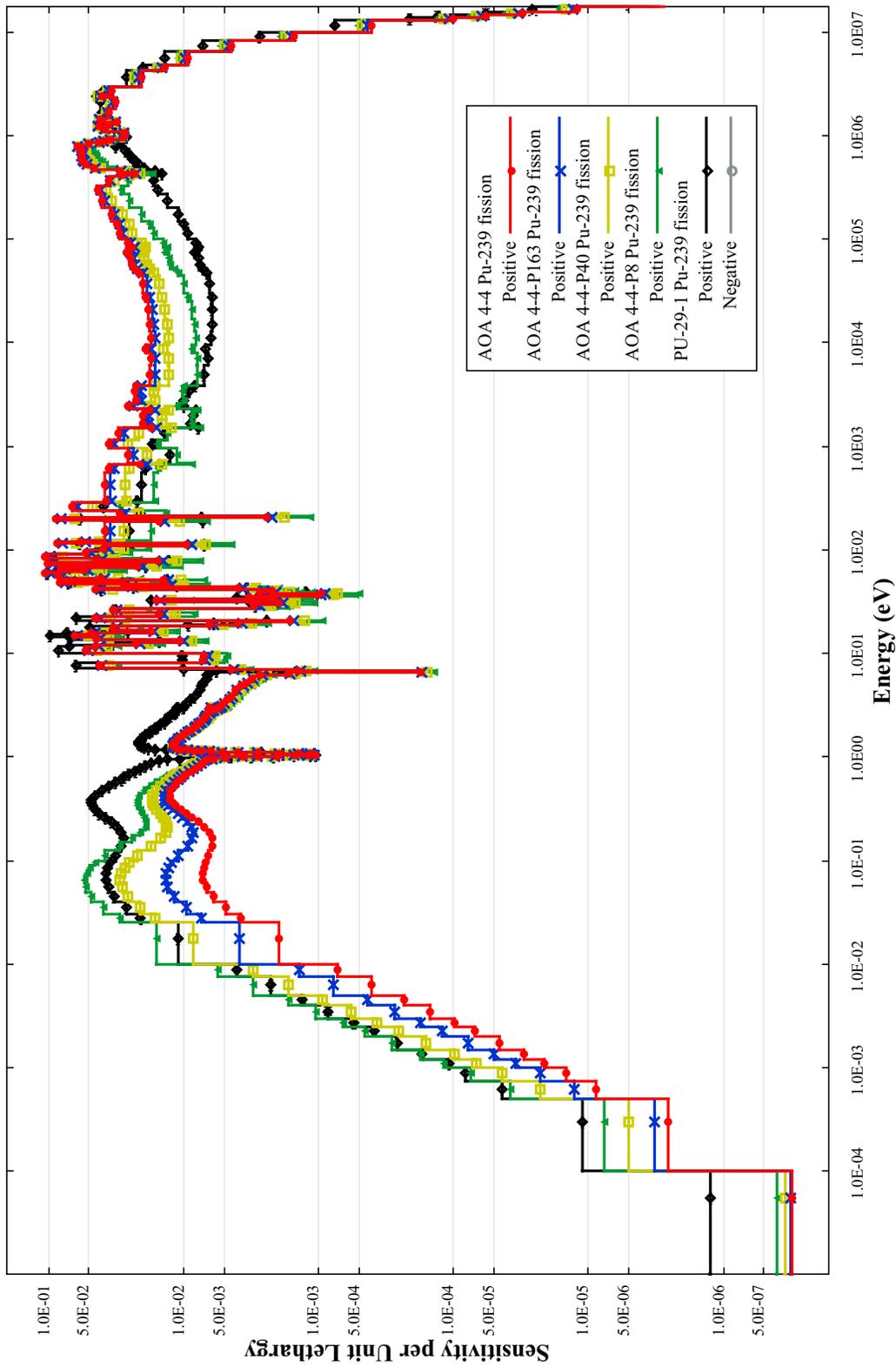
Fig. 3. Energy-dependent-sensitivity profiles for ^{239}Pu fission for varying mass cases of AOA 4-4 and benchmark experiment PU-29-1.

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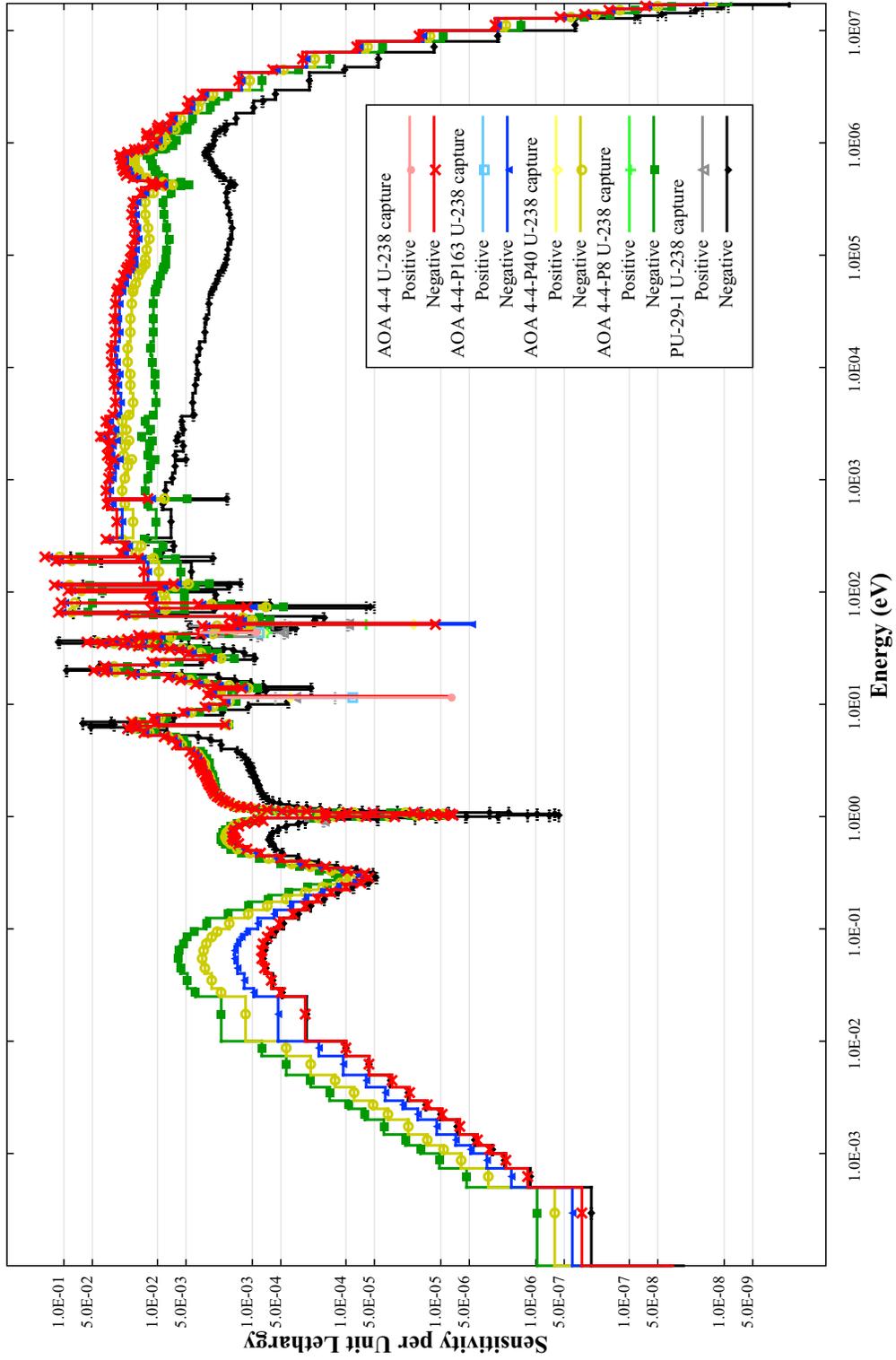
Fig. 4. Energy-dependent-sensitivity profiles for ^{238}U capture for varying mass cases of AOA 4-4 and benchmark experiment PU-29-1.

Thus, by reducing the mass of the system from a critical configuration to one that might be encountered by mass-control limits, several marked changes have been realized in the S/U analysis. Most notable is that the resultant changes in the system energy spectrum have reduced the sensitivity of the smaller systems to cross-section data in the fast region. This has produced more similarity between the design applications and the benchmark experiments.

This exercise has demonstrated that the selection of design systems used for validation studies should be carefully considered. The selection of the proper materials for analysis is crucial, but the geometrical limitations should also be given proper consideration.

6.2.3.   Identification of Additional Benchmarks for ^{238}U

Although the large-mass, high-density critical configuration of AOA 4-4 is not likely a realistic system from a facility design perspective, it provides an instructive example for the detailed use of the S/U tools. Further investigations of this system were conducted to identify additional data that might be useful to provide full coverage for this system. It was noted in the previous section that ^{238}U capture and fission reactions do not appear to be well covered for the critical configuration of AOA 4-4. In a search for experiments with similar sensitivities to ^{238}U, the dry uranium benchmarks, LEU-COMP-THERM-049, were identified. Although the c_k values for AOA 4-4 with these experiments are only in the range of 0.25, the $T(c_k)$ values for ^{238}U fission are ~0.8 for some experimental configurations and $T(c_k)$ values for ^{238}U capture are ~1.0 for all experimental configurations. For the subcritical configuration, AOA 4-4-P8, LEU-COMP-THERM-049 experiments again exhibit c_k values of about 0.25. The $T(c_k)$ values for ^{238}U fission are somewhat lower at about 0.4, but the $T(c_k)$ values for ^{238}U capture are about 1.5. Fig. 5 depicts the energy-dependent-sensitivity profiles for ^{238}U capture for AOA 4-4 and AOA 4-4-P8 along with those from experiments PU-29-1 and LEU-COMP-THERM-049-01. It can be observed from this figure that the profile from the uranium benchmark more closely matches that of the critical AOA 4-4 than does the MOX benchmark, PU-29-1, at fast energies. Also the uranium benchmark profile exceeds the other systems in the thermal region. At fast energies, the uranium benchmarks closely match the behavior of the subcritical design system AOA 4-4-P8.

If a technique, such as the generalized trending tool GLLSM, was applied to AOA 4-4 using a combination of MOX and LEU benchmarks, it is possible that full coverage of important reactions could be achieved. A scoping study was performed to determine the completeness parameter, and thus, the applicability of GLLSM using the selected benchmarks for this application. These results are shown in Appendix A.
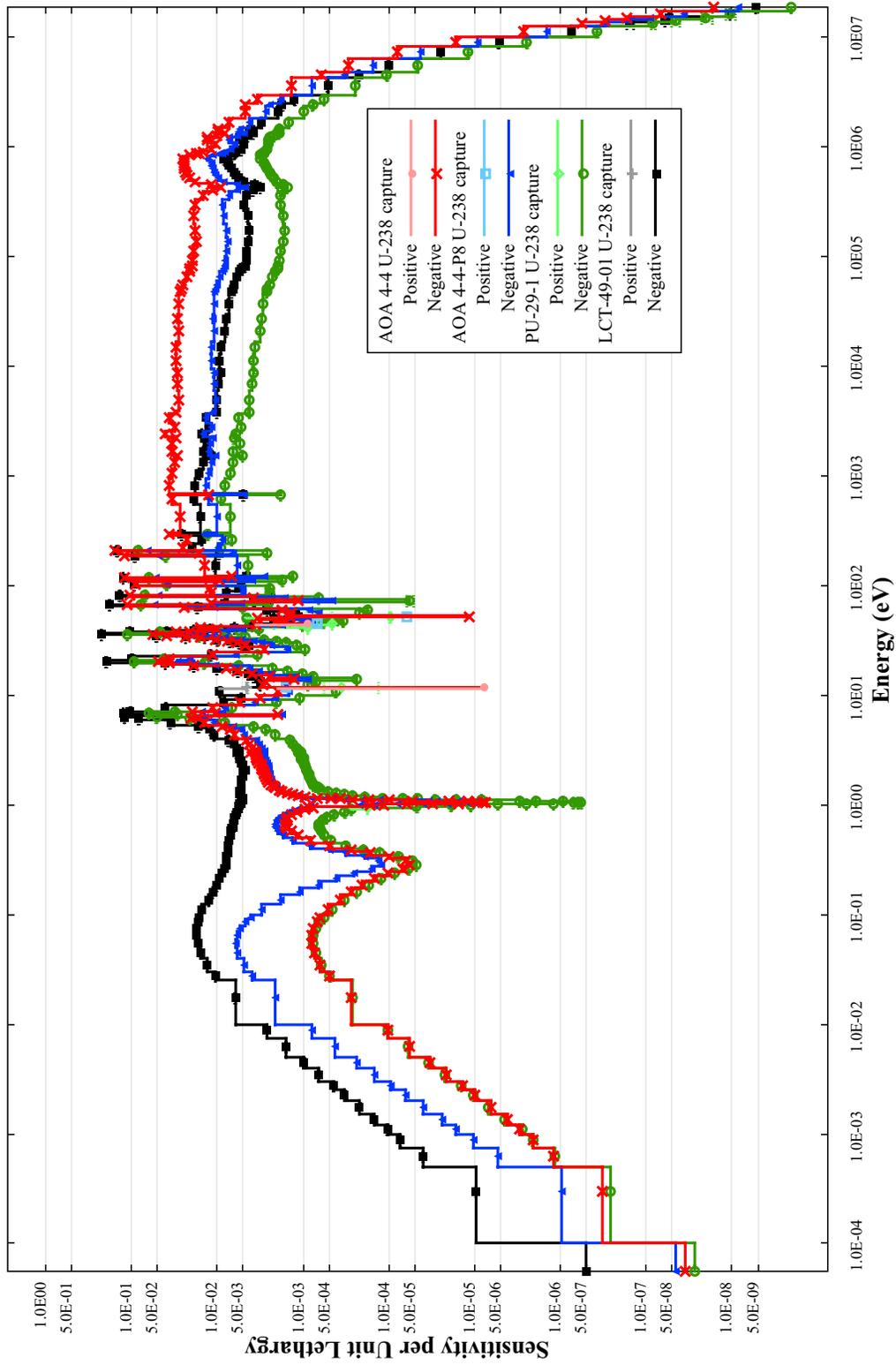
Fig. 5. Energy-dependent-sensitivity profiles for ^{238}U capture for AOA 4-4, AOA 4-4-P8, PU-29-1 and LEU-COMP-THERM-049-01.

7. CONCLUSIONS

This S/U study has identified a number critical benchmark experiments that exceed the previously established criterion for applicability to the criticality code validation for AOA 3, PuO$_2$ powders, and AOA 4, MOX powders, of the MFFF. This criterion is that the correlation coefficient, c_k, meets or exceeds a value of 0.8.

In this study, SEN3 was used to generate sensitivity data for 318 benchmark experiments. Also, SEN1 was used to generate sensitivity data for seven design application compositions provided by DCS as typical of those encountered in the MFFF. Of the analyzed applications, three are from AOA 3 and four are from AOA 4. The CANDE code generated correlation coefficients relating the similarity of each benchmark to each application. This data was tabulated, and those experiments exceeding the criterion for the correlation coefficient were reported.

For AOA 3, PuO$_2$ powders, the S/U methods demonstrate that the series of plutonium benchmarks identified by DCS as applicable to the criticality code validation exceed the S/U criteria for the three design systems evaluated. Of the 46 benchmarks identified by DCS, 38 were confirmed by the S/U methods as applicable to the PuO$_2$ powder systems. In addition to the experiments identified by DCS, additional plutonium and MOX benchmarks are available that exceed the S/U criterion for this AOA.

For AOA 4, MOX powders, the S/U methods demonstrate that the series of MOX benchmarks identified by DCS as applicable to the criticality code validation exceed the S/U criteria for critical configurations of three of the four compositions studied. These benchmarks meet the S/U criterion for subcritical configurations of the fourth composition. Additional MOX benchmarks included in this study also demonstrate high correlation coefficients with the design systems from this AOA. Additionally, several plutonium-fueled benchmarks exhibit high correlation coefficients with a subset of the MOX design systems studied.

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APPENDIX A

COMPLETENESS PARAMETER

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COMPLETENESS PARAMETER

Previously developed guidelines relate the number of systems and the magnitude of c_k parameters for which convergence of the GLLSM and hence convergences of trending studies with c_k are expected. However, the GLLSM procedure is useful for general purpose trending when the values of c_k are outside of the range of applicability. For these situations another parameter was developed to ensure that the set of benchmarks is "complete" in the sense that it completely tests all the important cross section elements in the particular application of interest. The availability of sensitivity coefficients provides a key element in the definition of this completeness parameter.

The completeness value, R, is defined as follows:

$$R = S_a / S_t \tag{A.1}$$

where

$$S_t = \sum_i \sum_j \sum_x |S_{xaij}|,$$

$$S_a = \sum_i \sum_j \sum_x |dS_{xaij}|,$$

and

$$d = \begin{cases} 1, & \text{if } N_{ix}^j > 9 \\ 0, & \text{if } N_{ix}^j \leq 9 \end{cases}$$

N_{ix}^j =   number of systems for which $S_{xeij} > |0.9 \times S_{xaij}|$

e   =   experiment

a   =   application

S_{xij} =   the sensitivity of k_{eff} to the cross sections of the constituent material nuclide j

i,x   =   indices for reaction and energy group.

The completeness value is designed to give the effective fraction of the total sensitivity for each application system that is "covered" by the benchmark set. This coverage is defined by comparing the magnitude of each group-wise sensitivity coefficient for the application with respect to each of the corresponding sensitivities of the benchmark systems. The minimum

coverage of these sensitivities for the benchmark systems is defined as 90% of the application sensitivity, hence the value of 0.9 in the definition of N_{ix}^{j}.

Work is planned but has not been completed to determine the magnitude of the R parameter, such that completeness is assured. Until then, the R-value is useful only in relative comparisons, i.e., the higher the number the better coverage for important reactions in the system. Note, the completeness parameter is a sensitivity-only parameter; the cross-section-covariance data is not included in its computation.

For this study, an evaluation of this completeness parameter was conducted to determine if the GLLSM methods would be useful for the determination of a computational bias for the critical configuration of AOA 4-4, where no benchmarks exceeded the 0.8 criterion for c_k. The results of this evaluation are given in Table A.1. These completeness parameters were computed in reference to the entire 318-experiment benchmark suite, including the LEU experiments that demonstrate a high $T(c_k)$ value for ^{238}U capture for AOA 4-4. As can be seen from this table, AOA 4-4 exhibits a very low completeness parameter relative to the other applications studied. Thus, addition benchmarks would need to be identified before reliable GLLSM results could be produced.

Table A.1. Completeness parameter (R) for each design system
using the 318-benchmark-experiment set

Application	Completeness parameter
AOA 3-1	0.6724
AOA 3-2	0.7835
AOA 3-3	0.7943
AOA 4-1	0.8271
AOA 4-2	0.5784
AOA 4-3	0.6292
AOA 4-4	0.4433
AOA 4-4-P163	0.5055
AOA 4-4-P40	0.6137
AOA 4-4-P8	0.6816

APPENDIX B

INTEGRAL VALUES

Table B.1. Tabulated c_k values and calculated parameters for design systems and benchmark experiments

Experiment	c_k for AOA 3-1	c_k for AOA 3-2	c_k for AOA 3-3	c_k for AOA 4-1	c_k for AOA 4-2	c_k for AOA 4-3	c_k for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
BNWL2129T3-01	0.2585	0.6120	0.4878	0.6339	0.5273	0.6734	0.3957	30.6	0.146	7.97	1.44E-01	1.0184	0.0005
BNWL2129T3-02	0.2580	0.6124	0.4882	0.6347	0.5286	0.6750	0.3973	30.6	0.146	7.97	1.46E-01	1.0195	0.0006
BNWL2129T3-03	0.2601	0.6146	0.4904	0.6373	0.5318	0.6767	0.4011	30.6	0.146	7.97	1.47E-01	1.0187	0.0005
BNWL2129T3-04	0.2593	0.6150	0.4907	0.6380	0.5329	0.6781	0.4023	30.6	0.146	7.97	1.49E-01	1.021	0.0006
BNWL2129T3-05	0.2572	0.6145	0.4901	0.6376	0.5331	0.6793	0.4029	30.6	0.146	7.97	1.50E-01	1.0219	0.0006
BNWL2129T3-06	0.2570	0.6150	0.4904	0.6383	0.5340	0.6804	0.4036	30.6	0.146	7.97	1.51E-01	1.0213	0.0006
BNWL2129T3-07	0.2572	0.6146	0.4901	0.6378	0.5335	0.6795	0.4033	30.6	0.146	7.97	1.52E-01	1.0206	0.0006
BNWL2129T3-08	0.2600	0.6171	0.4927	0.6406	0.5360	0.6811	0.4052	30.6	0.146	7.97	1.53E-01	1.0189	0.0005
BNWL2129T3-09	0.2602	0.6174	0.4931	0.6412	0.5370	0.6819	0.4064	30.6	0.146	7.97	1.54E-01	1.0179	0.0006
BNWL2129T3-10	0.2594	0.6173	0.4929	0.6412	0.5372	0.6824	0.4067	30.6	0.146	7.97	1.54E-01	1.0199	0.0006
BNWL2129T3-11	0.2576	0.6164	0.4920	0.6404	0.5365	0.6827	0.4059	30.6	0.146	7.97	1.55E-01	1.0197	0.0006
BNWL2129T3-12	0.2589	0.6162	0.4921	0.6403	0.5368	0.6821	0.4069	30.6	0.146	7.97	1.55E-01	1.0178	0.0006
BNWL2129T3-13A	0.2603	0.6175	0.4932	0.6413	0.5368	0.6816	0.4058	30.6	0.146	7.97	1.54E-01	1.0179	0.0006
BNWL2129T3-14	0.2600	0.6173	0.4932	0.6415	0.5378	0.6826	0.4075	30.6	0.146	7.97	1.55E-01	1.0176	0.0005
BNWL2129T3-15	0.2588	0.6164	0.4922	0.6405	0.5368	0.6824	0.4066	30.6	0.146	7.97	1.55E-01	1.0175	0.0007
BNWL2129T3-16	0.2578	0.6105	0.4870	0.6428	0.5382	0.6906	0.4032	30.6	0.146	7.97	1.68E-01	1.0195	0.0006
BNWL2129T3-17	0.2551	0.6075	0.4845	0.6481	0.5494	0.7083	0.4198	30.6	0.146	7.97	2.04E-01	1.0195	0.0006
BNWL2129T3-18	0.2537	0.6061	0.4836	0.6477	0.5609	0.7215	0.4525	30.6	0.146	7.97	2.46E-01	1.0181	0.0006
BNWL2129T3-19	0.2542	0.6061	0.4836	0.6459	0.5626	0.7216	0.4614	30.6	0.146	7.97	2.57E-01	1.0173	0.0005
BNWL2129T3-20	0.2597	0.6171	0.4928	0.6412	0.5371	0.6822	0.4063	30.6	0.146	7.97	1.54E-01	1.0239	0.0006
BNWL2129T3-21	0.2597	0.6172	0.4930	0.6412	0.5373	0.6820	0.4065	30.6	0.146	7.97	1.55E-01	1.0234	0.0006
BNWL2129T3-22	0.2604	0.6164	0.4925	0.6405	0.5368	0.6812	0.4069	30.6	0.146	7.97	1.56E-01	1.0216	0.0006
BNWL2129T3-23	0.2595	0.6159	0.4919	0.6400	0.5363	0.6815	0.4065	30.6	0.146	7.97	1.55E-01	1.0207	0.0006
BNWL2129T3-24	0.2568	0.6157	0.4913	0.6398	0.5363	0.6826	0.4064	30.6	0.146	7.97	1.56E-01	1.0457	0.0007
BNWL2129T3-25	0.2618	0.6179	0.4940	0.6416	0.5375	0.6811	0.4070	30.6	0.146	7.97	1.53E-01	0.9862	0.0007
BNWL2129T3-26	0.2602	0.6163	0.4925	0.6401	0.5362	0.6810	0.4057	30.6	0.146	7.97	1.53E-01	0.9775	0.0007
BNWL2129T3-27	0.2555	0.6197	0.4946	0.6407	0.5345	0.6767	0.4014	30.6	0.146	7.97	1.44E-01	1.0194	0.0006

Table B.1 (continued)

Experiment	c_k for AOA 3-1	c_k for AOA 3-2	c_k for AOA 3-3	c_k for AOA 4-1	c_k for AOA 4-2	c_k for AOA 4-3	c_k for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
BNWL2129T3-28	0.2595	0.6111	0.4871	0.6332	0.5271	0.6731	0.3967	30.6	0.146	7.97	1.43E-01	1.021	0.0006
BNWL2129T3-29	0.2578	0.6112	0.4870	0.6331	0.5271	0.6734	0.3966	30.6	0.146	7.97	1.43E-01	1.0203	0.0006
BNWL2129T3-30	0.2585	0.6115	0.4873	0.6334	0.5274	0.6734	0.3975	30.6	0.146	7.97	1.43E-01	1.0214	0.0006
BNWL2129T3-31	0.2581	0.6104	0.4864	0.6323	0.5266	0.6726	0.3972	30.6	0.146	7.97	1.43E-01	1.0216	0.0006
BNWL2129T4-01	0.3496	0.9005	0.8073	0.9367	0.8651	0.8441	0.6673	7.13	0.28	10.95	6.13E+00	1.0184	0.0006
BNWL2129T4-02	0.3504	0.8909	0.7954	0.9268	0.8557	0.8414	0.6666	7.64	0.28	10.89	4.51E+00	1.0178	0.0006
BNWL2129T4-03	0.3391	0.8602	0.7574	0.8947	0.8173	0.8313	0.6359	8.08	0.27	10.83	3.44E+00	1.018	0.0007
BNWL2129T4-04	0.3551	0.8888	0.7942	0.9258	0.8532	0.8402	0.6619	7.51	0.28	10.9	5.08E+00	1.0182	0.0005
BNWL2129T4-05	0.3413	0.8476	0.7439	0.8824	0.8016	0.8244	0.6215	8.29	0.27	10.8	3.22E+00	1.0183	0.0006
BNWL2129T4-06	0.3282	0.8074	0.6980	0.8410	0.7548	0.8055	0.5840	8.81	0.27	10.74	2.24E+00	1.018	0.0005
BNWL2129T4-07	0.3599	0.8856	0.7915	0.9230	0.8509	0.8391	0.6632	7.57	0.28	10.89	4.91E+00	1.0165	0.0005
BNWL2129T4-08	0.3413	0.8292	0.7242	0.8640	0.7823	0.8181	0.6103	8.71	0.27	10.75	2.40E+00	1.0186	0.0005
BNWL2129T4-09	0.3481	0.8855	0.7897	0.9261	0.8543	0.8468	0.6628	7.39	0.28	10.92	5.78E+00	1.0187	0.0006
BNWL2129T4-10	0.3451	0.8617	0.7622	0.9043	0.8353	0.8482	0.6623	7.72	0.28	10.88	5.24E+00	1.0159	0.0006
BNWL2129T4-11	0.3277	0.8204	0.7141	0.8648	0.7966	0.8407	0.6408	8.52	0.27	10.77	3.48E+00	1.0166	0.0005
BNWL2129T4-12	0.3470	0.8699	0.7705	0.9054	0.8282	0.8340	0.6415	8.09	0.27	10.83	3.84E+00	1.02	0.0005
BNWL2129T4-13	0.3480	0.8192	0.7147	0.8549	0.7710	0.8104	0.5996	8.79	0.27	10.74	2.47E+00	1.0214	0.0007
BNWL2129T4-14	0.3183	0.7608	0.6475	0.7921	0.7006	0.7784	0.5423	9.37	0.27	10.67	1.51E+00	1.0196	0.0006
BNWL2129T4-15	0.3545	0.8867	0.7913	0.9224	0.8505	0.8402	0.6638	7.51	0.28	10.9	5.08E+00	1.0161	0.0005
BNWL2129T4-16	0.3498	0.8885	0.7925	0.9237	0.8508	0.8405	0.6609	7.37	0.28	10.92	5.24E+00	1.0178	0.0006
BNWL2129T4-17	0.3499	0.8844	0.7874	0.9193	0.8452	0.8377	0.6561	7.68	0.28	10.88	4.28E+00	1.0172	0.0005
BNWL2129T4-18	0.3426	0.8581	0.7558	0.8921	0.8131	0.8283	0.6313	7.91	0.27	10.85	3.58E+00	1.0171	0.0005
BNWL2129T4-19	0.3386	0.8724	0.7715	0.9068	0.8287	0.8347	0.6385	7.79	0.27	10.87	4.05E+00	1.0181	0.0006
LCT049-01	0.0022	0.0059	0.0055	0.1670	0.2224	0.4225	0.2845	2.0124	0	0	2.19E+00	0.9902	0.0007
LCT049-02	0.0037	0.0072	0.0067	0.1695	0.2232	0.4215	0.2779	2.0124	0	0	2.21E+00	0.9912	0.0006
LCT049-03	0.0023	0.0061	0.0056	0.1690	0.2222	0.4246	0.2810	2.0124	0	0	2.34E+00	0.9918	0.0005
LCT049-04	0.0032	0.0067	0.0062	0.1694	0.2245	0.4254	0.2842	2.0124	0	0	2.36E+00	0.9957	0.0005
LCT049-05	0.0030	0.0070	0.0064	0.1660	0.2119	0.4086	0.2552	2.5164	0	0	1.23E+00	0.9902	0.0005
LCT049-06	0.0054	0.0091	0.0084	0.1711	0.2134	0.4101	0.2454	2.5164	0	0	1.25E+00	0.9919	0.0006

Table B.1 (continued)

Experiment	c_k for AOA 3-1	c_k for AOA 3-2	c_k for AOA 3-3	c_k for AOA 4-1	c_k for AOA 4-2	c_k for AOA 4-3	c_k for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
LCT049-07	0.0055	0.0092	0.0085	0.1707	0.2117	0.4070	0.2413	2.5164	0	0	1.20E+00	0.9897	0.0006
LCT049-08	0.0036	0.0077	0.0071	0.1662	0.2119	0.4070	0.2539	2.5164	0	0	1.29E+00	0.9906	0.0006
LCT049-09	0.0060	0.0101	0.0093	0.1680	0.2041	0.3979	0.2268	3.0067	0	0	7.94E-01	0.9901	0.0005
LCT049-10	0.0074	0.0111	0.0102	0.1699	0.2043	0.3973	0.2220	3.0067	0	0	8.00E-01	0.9912	0.0007
LCT049-11	0.0071	0.0109	0.0100	0.1695	0.2039	0.3960	0.2209	3.0067	0	0	7.95E-01	0.9899	0.0006
LCT049-12	0.0058	0.0099	0.0090	0.1681	0.2055	0.4003	0.2307	3.0067	0	0	8.39E-01	0.9898	0.0006
LCT049-13	0.0058	0.0094	0.0087	0.1748	0.2171	0.4158	0.2466	3.0067	0	0	1.53E+00	0.9891	0.0006
LCT049-14	0.0050	0.0088	0.0082	0.1734	0.2179	0.4189	0.2544	3.0067	0	0	1.53E+00	0.9898	0.0006
LCT049-15	0.0049	0.0087	0.0080	0.1730	0.2175	0.4169	0.2531	3.0067	0	0	1.54E+00	0.9906	0.0007
LCT049-16	0.0054	0.0091	0.0084	0.1701	0.2123	0.4081	0.2447	3.0067	0	0	1.19E+00	0.9907	0.0006
LCT049-17	0.0037	0.0078	0.0072	0.1676	0.2145	0.4127	0.2593	3.0067	0	0	1.28E+00	0.9905	0.0005
LCT049-18	0.0017	0.0061	0.0056	0.1593	0.2083	0.4016	0.2620	3.0067	0	0	1.09E+00	0.9943	0.0006
MCT001-01	0.3018	0.7873	0.6709	0.8112	0.7105	0.7630	0.5201	3.3346	0.2237	11.5414	1.61E-03	1.0022	0.0005
MCT001-02	0.2969	0.6806	0.5640	0.6904	0.5753	0.6610	0.4136	6.8576	0.2237	11.5414	4.76E-04	1.0012	0.0006
MCT001-03	0.2774	0.6399	0.5247	0.6447	0.5313	0.6184	0.3841	10.8808	0.2237	11.5414	2.91E-04	1.0025	0.0007
MCT001-04	0.4133	0.1539	0.1132	0.1878	0.0769	0.2671	0.0737	17.5335	0.2237	11.5414	2.11E-04	1.004	0.0006
MCT002-01	0.2417	0.5887	0.4778	0.6924	0.6135	0.8032	0.4744	1.1946	0.0204	7.7593	5.79E-01	0.9934	0.0006
MCT002-02	0.2497	0.5938	0.4837	0.7007	0.6320	0.8233	0.5092	1.1946	0.0204	7.7593	7.73E-01	0.9958	0.0006
MCT002-03	0.2689	0.5625	0.4515	0.6272	0.5181	0.6796	0.3681	2.5249	0.0204	7.7593	1.93E-01	0.999	0.0006
MCT002-04	0.2727	0.5822	0.4689	0.6520	0.5608	0.7279	0.4401	2.5249	0.0204	7.7593	2.82E-01	1.005	0.0007
MCT002-05	0.2757	0.5531	0.4429	0.6016	0.4870	0.6343	0.3437	3.641	0.0204	7.7593	1.38E-01	1.004	0.0006
MCT002-06	0.2775	0.5689	0.4563	0.6209	0.5213	0.6729	0.4043	3.641	0.0204	7.7593	1.83E-01	1.0063	0.0006
MCT003-01	0.2730	0.7032	0.5863	0.7700	0.6742	0.7961	0.4940	1.6814	0.0659	8.5826	9.06E-01	0.9931	0.0006
MCT003-02	0.2762	0.6771	0.5595	0.7336	0.6285	0.7534	0.4505	2.1645	0.0659	8.5826	5.50E-01	0.9942	0.0007
MCT003-03	0.2768	0.6872	0.5696	0.7479	0.6464	0.7697	0.4661	2.1645	0.0659	8.5826	6.56E-01	0.9939	0.0006
MCT003-04	0.2851	0.6116	0.4969	0.6420	0.5220	0.6430	0.3625	4.7057	0.0659	8.5826	1.88E-01	0.9984	0.0006
MCT003-05	0.2869	0.6002	0.4864	0.6250	0.5038	0.6223	0.3507	5.672	0.0659	8.5826	1.56E-01	0.9987	0.0007
MCT003-06	0.2909	0.5675	0.4574	0.5800	0.4572	0.5676	0.3231	10.7543	0.0659	8.5826	1.01E-01	1.0023	0.0006
MCT004-01	0.2623	0.5473	0.4375	0.6029	0.4975	0.6577	0.3601	2.4201	0.03	22.0825	1.46E-01	0.9936	0.0006

Table B.1 (continued)

Experiment	c_k for AOA 3-1	c_k for AOA 3-2	c_k for AOA 3-3	c_k for AOA 4-1	c_k for AOA 4-2	c_k for AOA 4-3	c_k for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
MCT004-02	0.2628	0.5461	0.4364	0.6021	0.4964	0.6575	0.3588	2.4201	0.0299	22.1504	1.45E-01	0.9951	0.0005
MCT004-03	0.2633	0.5472	0.4372	0.6030	0.4970	0.6581	0.3592	2.4201	0.028	23.7291	1.45E-01	0.9956	0.0006
MCT004-04	0.2661	0.5400	0.4311	0.5872	0.4785	0.6307	0.3443	2.9761	0.03	22.078	1.21E-01	0.9951	0.0007
MCT004-05	0.2663	0.5410	0.4318	0.5880	0.4795	0.6321	0.3460	2.9761	0.0299	22.1521	1.20E-01	0.9962	0.0006
MCT004-06	0.2676	0.5430	0.4334	0.5895	0.4809	0.6336	0.3485	2.9761	0.0298	22.289	1.19E-01	0.998	0.0006
MCT004-07	0.2694	0.5302	0.4227	0.5645	0.4532	0.5924	0.3277	4.2387	0.03	22.0708	9.34E-02	0.9983	0.0006
MCT004-08	0.2704	0.5322	0.4244	0.5662	0.4549	0.5939	0.3302	4.2387	0.0299	22.1533	9.31E-02	0.9992	0.0006
MCT004-09	0.2708	0.5332	0.4252	0.5671	0.4559	0.5950	0.3315	4.2387	0.0298	22.2246	9.28E-02	0.9995	0.0006
MCT004-10	0.2708	0.5226	0.4165	0.5487	0.4375	0.5673	0.3211	5.5521	0.03	22.0739	8.05E-02	0.9991	0.0007
MCT004-11	0.2716	0.5241	0.4177	0.5502	0.4386	0.5683	0.3217	5.5521	0.0299	22.155	8.02E-02	1.0004	0.0006
MCT005-01	0.2781	0.6171	0.5025	0.6877	0.5817	0.7276	0.4253	2.2187	0.0399	18.2054	3.82E-04	0.9964	0.0005
MCT005-02	0.2831	0.5995	0.4857	0.6562	0.5417	0.6812	0.3881	2.8531	0.0399	18.2054	2.54E-04	0.9954	0.0005
MCT005-03	0.2867	0.5748	0.4635	0.6170	0.4969	0.6240	0.3529	3.9116	0.0399	18.2054	1.73E-04	1.004	0.0006
MCT005-04	0.2862	0.5574	0.4485	0.5907	0.4697	0.5872	0.3355	4.8202	0.0399	18.2054	1.39E-04	1.028	0.0006
MCT005-05	0.2878	0.5335	0.4283	0.5531	0.4318	0.5361	0.3138	7.558	0.0399	18.2054	1.03E-04	1.0068	0.0006
MCT005-06	0.2483	0.4277	0.3427	0.4355	0.3296	0.3975	0.2490	10.4047	0.0399	18.2054	8.80E-05	1.0058	0.0004
MCT005-07	0.2771	0.4971	0.3980	0.5072	0.3925	0.4825	0.2986	11.8748	0.0399	18.2054	8.30E-05	1.0068	0.0006
MCT008-01	0.2487	0.5565	0.4479	0.6591	0.5807	0.7784	0.4601	1.7672	0.02	23.5804	3.99E-01	0.9921	0.0005
MCT008-02	0.2587	0.5444	0.4353	0.6205	0.5214	0.6950	0.3854	2.7396	0.02	23.5727	1.99E-01	0.9958	0.0005
MCT008-03	0.2647	0.5372	0.4286	0.5956	0.4906	0.6477	0.3597	3.7669	0.02	23.588	1.42E-01	0.9978	0.0005
MCT008-04	0.2662	0.5312	0.4235	0.5803	0.4733	0.6211	0.3476	4.6486	0.02	23.6031	1.19E-01	1.0021	0.0005
MCT008-05	0.2688	0.5220	0.4158	0.5571	0.4500	0.5831	0.3389	6.5336	0.02	23.5994	9.67E-02	1.0032	0.0005
MCT008-06	0.2687	0.5181	0.4126	0.5495	0.4428	0.5720	0.3365	7.3056	0.02	23.5727	9.17E-02	1.0026	0.0006
MCT008-07	0.2697	0.5233	0.4172	0.5776	0.4673	0.6082	0.3451	3.7669	0.02	23.588	1.41E-01	0.998	0.0005
MCT008-08	0.2709	0.5308	0.4232	0.5868	0.4763	0.6218	0.3509	3.7669	0.02	23.588	1.41E-01	0.9954	0.0007
MCT008-09	0.2708	0.5304	0.4229	0.5861	0.4761	0.6209	0.3522	3.7669	0.02	23.588	1.42E-01	0.9955	0.0006
MCT008-10	0.2713	0.5334	0.4253	0.5899	0.4796	0.6268	0.3536	3.7669	0.02	23.588	1.42E-01	0.9944	0.0006
MCT008-11	0.2512	0.4584	0.3660	0.5007	0.3966	0.5077	0.2967	3.7669	0.02	23.588	1.42E-01	0.9944	0.0005
MCT008-12	0.2547	0.4671	0.3730	0.5107	0.4050	0.5194	0.3016	3.7669	0.02	23.588	1.42E-01	0.9931	0.0005

Table B.1 (continued)

Experiment	c_k for AOA 3-1	c_k for AOA 3-2	c_k for AOA 3-3	c_k for AOA 4-1	c_k for AOA 4-2	c_k for AOA 4-3	c_k for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
MCT008-13	0.2497	0.4537	0.3624	0.4953	0.3915	0.5004	0.2922	3.7669	0.02	23.588	1.41E-01	0.9951	0.0005
MCT008-14	0.2537	0.4636	0.3703	0.5066	0.4013	0.5143	0.2990	3.7669	0.02	23.588	1.42E-01	0.9947	0.0005
MCT008-15	0.2539	0.4651	0.3714	0.5092	0.4031	0.5173	0.2984	3.7669	0.02	23.588	1.42E-01	0.9943	0.0005
MCT008-16	0.2565	0.4721	0.3770	0.5163	0.4103	0.5270	0.3065	3.7669	0.02	23.588	1.42E-01	0.9935	0.0005
MCT008-17	0.2559	0.4713	0.3764	0.5160	0.4099	0.5265	0.3053	3.7669	0.02	23.588	1.43E-01	0.9948	0.0005
MCT008-18	0.2524	0.4625	0.3693	0.5055	0.4014	0.5145	0.3016	3.7669	0.02	23.588	1.42E-01	0.9931	0.0006
MCT008-19	0.2564	0.4719	0.3769	0.5161	0.4105	0.5266	0.3074	3.7669	0.02	23.588	1.42E-01	0.9942	0.0005
MCT008-20	0.2533	0.4644	0.3709	0.5075	0.4032	0.5169	0.3029	3.7669	0.02	23.588	1.43E-01	0.9933	0.0005
MCT008-21	0.2556	0.4704	0.3756	0.5141	0.4092	0.5251	0.3078	3.7669	0.02	23.588	1.43E-01	0.9937	0.0005
MCT008-22	0.2579	0.4761	0.3803	0.5214	0.4148	0.5330	0.3091	3.7669	0.02	23.588	1.43E-01	0.9934	0.0005
MCT008-23	0.2533	0.4646	0.3710	0.5079	0.4033	0.5169	0.3020	3.7669	0.02	23.588	1.43E-01	0.9936	0.0006
MCT008-24	0.2579	0.4763	0.3804	0.5211	0.4151	0.5331	0.3109	3.7669	0.02	23.588	1.43E-01	0.993	0.0005
MCT008-25	0.2526	0.4626	0.3694	0.5054	0.4011	0.5139	0.3008	3.7669	0.02	23.588	1.43E-01	0.9941	0.0005
MCT008-26	0.2544	0.4676	0.3733	0.5115	0.4062	0.5213	0.3035	3.7669	0.02	23.588	1.43E-01	0.9934	0.0006
MCT008-27	0.2503	0.4568	0.3648	0.4990	0.3956	0.5064	0.2972	3.7669	0.02	23.588	1.43E-01	0.9927	0.0006
MCT008-28	0.2514	0.4594	0.3669	0.5020	0.3981	0.5094	0.2983	3.7669	0.02	23.588	1.43E-01	0.9931	0.0006
MCT009-01	0.2485	0.5649	0.4546	0.6735	0.6053	0.8189	0.5079	1.4103	0.015	7.8651	5.52E-01	0.9945	0.0005
MCT009-02	0.2618	0.5617	0.4495	0.6517	0.5616	0.7576	0.4420	1.8685	0.015	7.8647	3.08E-01	0.9923	0.0005
MCT009-03	0.2720	0.5500	0.4384	0.6120	0.5055	0.6740	0.3778	3.0167	0.015	7.8643	1.57E-01	0.9956	0.0005
MCT009-04	0.2773	0.5440	0.4331	0.5904	0.4791	0.6311	0.3573	4.0995	0.015	7.8643	1.18E-01	0.9969	0.0006
MCT009-05	0.2811	0.5347	0.4255	0.5688	0.4547	0.5902	0.3428	5.4541	0.015	7.8643	9.61E-02	0.9998	0.0005
MCT009-06	0.2796	0.5331	0.4242	0.5644	0.4513	0.5848	0.3409	5.8916	0.015	7.8647	9.06E-02	0.9913	0.0006
MCT011-01	0.2579	0.5682	0.4838	0.5612	0.4707	0.5137	0.3418	11.7459	0.2573	9.7532	5.66E-01	1.0023	0.0006
MCT011-02	0.2581	0.5606	0.4769	0.5534	0.4624	0.5082	0.3351	11.7459	0.2573	9.7532	5.55E-01	1.0033	0.0006
MCT011-03	0.2570	0.5588	0.4751	0.5511	0.4597	0.5058	0.3325	11.7459	0.2573	9.7532	5.35E-01	1.0011	0.0006
MCT011-04	0.2705	0.5314	0.4468	0.5225	0.4246	0.4829	0.3095	21.1287	0.2573	9.7532	2.50E-01	1.0018	0.0006
MCT011-05	0.2713	0.5338	0.4491	0.5250	0.4271	0.4845	0.3110	21.1287	0.2573	9.7532	2.57E-01	1.0009	0.0005
MCT011-06	0.2695	0.5368	0.4516	0.5280	0.4303	0.4872	0.3135	21.1287	0.2573	9.7532	2.64E-01	1.0007	0.0006
MCT012-01	0.2564	0.5732	0.4562	0.6214	0.5263	0.7018	0.4118	39.5351	0.0758	23.0093	1.39E-01	0.9784	0.0006

Table B.1 (continued)

Experiment	c_k for AOA 3-1	c_k for AOA 3-2	c_k for AOA 3-3	c_k for AOA 4-1	c_k for AOA 4-2	c_k for AOA 4-3	c_k for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
MCT012-02	0.2570	0.5740	0.4570	0.6223	0.5271	0.7022	0.4125	39.5351	0.0758	23.0093	1.39E-01	0.9788	0.0006
MCT012-03	0.2572	0.5739	0.4569	0.6220	0.5267	0.7016	0.4124	39.5351	0.0758	23.0093	1.39E-01	0.9753	0.0005
MCT012-04	0.2563	0.5733	0.4564	0.6220	0.5268	0.7027	0.4117	39.5351	0.0758	23.0093	1.40E-01	0.9789	0.0007
MCT012-05	0.2564	0.5736	0.4566	0.6221	0.5269	0.7024	0.4119	39.5351	0.0758	23.0093	1.39E-01	0.9784	0.0006
MCT012-06	0.2553	0.5740	0.4568	0.6225	0.5273	0.7030	0.4115	39.5351	0.0758	23.0093	1.40E-01	0.9833	0.0005
MCT012-07	0.2647	0.5478	0.4325	0.5715	0.4632	0.6177	0.3565	101.7127	0.0788	8.1493	6.66E-02	1.0366	0.0006
MCT012-08	0.2648	0.5479	0.4326	0.5714	0.4631	0.6174	0.3567	101.7127	0.0788	8.1493	6.64E-02	1.0329	0.0006
MCT012-09	0.2653	0.5478	0.4326	0.5710	0.4627	0.6160	0.3568	101.7127	0.0788	8.1493	6.62E-02	1.0298	0.0006
MCT012-10	0.2652	0.5477	0.4325	0.5709	0.4626	0.6161	0.3567	101.7127	0.0788	8.1493	6.62E-02	1.0293	0.0006
MCT012-11	0.2653	0.5481	0.4328	0.5714	0.4630	0.6167	0.3568	101.7127	0.0788	8.1493	6.63E-02	1.0285	0.0006
MCT012-12	0.2651	0.5481	0.4328	0.5715	0.4631	0.6170	0.3568	101.7127	0.0788	8.1493	6.63E-02	1.0298	0.0006
MCT012-13	0.2651	0.5481	0.4328	0.5716	0.4632	0.6171	0.3565	101.7127	0.0788	8.1493	6.66E-02	1.0388	0.0006
MCT012-14	0.2552	0.6134	0.4888	0.6359	0.5298	0.6776	0.3970	60.6277	0.1461	8.0016	1.43E-01	1.0239	0.0006
MCT012-15	0.2555	0.6141	0.4895	0.6367	0.5308	0.6785	0.3985	60.6277	0.1461	8.0016	1.43E-01	1.0234	0.0006
MCT012-16	0.2553	0.6129	0.4883	0.6351	0.5290	0.6766	0.3971	60.6277	0.1461	8.0016	1.41E-01	1.0202	0.0007
MCT012-17	0.2543	0.6124	0.4878	0.6345	0.5284	0.6765	0.3966	60.6277	0.1461	8.0016	1.41E-01	1.0215	0.0007
MCT012-18	0.2563	0.6138	0.4892	0.6360	0.5300	0.6772	0.3986	60.6277	0.1461	8.0016	1.40E-01	1.0187	0.0007
MCT012-19	0.2570	0.6132	0.4887	0.6352	0.5290	0.6760	0.3984	60.6277	0.1461	8.0016	1.39E-01	1.0182	0.0006
MCT012-20	0.2457	0.6211	0.4957	0.6490	0.5477	0.7001	0.4084	60.6277	0.1461	8.0016	1.98E-01	1.0185	0.0007
MCT012-21	0.2464	0.6215	0.4962	0.6495	0.5481	0.7002	0.4087	60.6277	0.1461	8.0016	1.98E-01	1.0175	0.0006
MCT012-22	0.2449	0.6220	0.4955	0.6558	0.5533	0.7036	0.4155	60.6277	0.1461	8.0016	2.06E-01	1.0142	0.0007
MCT012-23	0.2556	0.6414	0.5141	0.6493	0.5419	0.6661	0.4015	95.4106	0.3001	8.1648	1.66E-01	1.0132	0.0007
MCT012-24	0.2545	0.6404	0.5130	0.6479	0.5401	0.6646	0.3999	95.4106	0.3001	8.1648	1.65E-01	1.0142	0.0006
MCT012-25	0.2536	0.6398	0.5124	0.6474	0.5399	0.6649	0.3998	95.4106	0.3001	8.1648	1.64E-01	1.0132	0.0006
MCT012-26	0.2546	0.6399	0.5126	0.6475	0.5398	0.6647	0.4002	95.4106	0.3001	8.1648	1.61E-01	1.0116	0.0007
MCT012-27	0.2562	0.6405	0.5133	0.6482	0.5406	0.6644	0.4013	95.4106	0.3001	8.1648	1.60E-01	1.0119	0.0007
MCT012-28	0.2555	0.6400	0.5128	0.6477	0.5400	0.6644	0.4010	95.4106	0.3001	8.1648	1.59E-01	1.0142	0.0006
MCT012-29	0.2562	0.6399	0.5127	0.6474	0.5396	0.6637	0.4008	95.4106	0.3001	8.1648	1.58E-01	1.0131	0.0008
MCT012-30	0.2570	0.6400	0.5129	0.6479	0.5402	0.6643	0.4011	95.4106	0.3001	8.1648	1.60E-01	1.0128	0.0006

Table B.1 (continued)

Experiment	c_k for AOA 3-1	c_k for AOA 3-2	c_k for AOA 3-3	c_k for AOA 4-1	c_k for AOA 4-2	c_k for AOA 4-3	c_k for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
MCT012-31	0.2437	0.6553	0.5268	0.6664	0.5647	0.6897	0.4165	95.4106	0.3001	8.1648	2.49E-01	0.9975	0.0007
MCT012-32	0.2434	0.6548	0.5263	0.6660	0.5644	0.6898	0.4163	95.4106	0.3001	8.1648	2.49E-01	0.9984	0.0008
MCT012-33	0.2431	0.6547	0.5262	0.6658	0.5641	0.6896	0.4160	95.4106	0.3001	8.1648	2.49E-01	0.9956	0.0007
MMF011-01	0.7929	0.6294	0.7904	0.6310	0.6208	0.3751	0.5026	0	0.414	6.16	2.79E+05	1.0009	0.0005
MMF011-02	0.7011	0.5324	0.6792	0.5365	0.5391	0.3238	0.4493	0	0.274	6.73	3.18E+05	1.0059	0.0005
MMF011-03	0.5076	0.4104	0.5127	0.4267	0.4350	0.2785	0.3686	0	0.178	7.88	2.07E+05	1.0088	0.0005
MMF011-04	0.2024	0.1580	0.1998	0.1830	0.1942	0.1327	0.1620	0	0.077	11.6	2.57E+05	1.0097	0.0006
MST001-01	0.2613	0.6255	0.5002	0.6408	0.5348	0.6696	0.4012	46.4302	0.2186	8.3098	1.61E-01	0.9969	0.0006
MST001-02	0.2611	0.6265	0.5012	0.6417	0.5358	0.6702	0.4018	46.2535	0.2196	8.31	1.62E-01	0.9966	0.0006
MST001-03	0.2623	0.6241	0.4990	0.6381	0.5309	0.6656	0.3963	46.2873	0.2213	8.3097	1.58E-01	0.9919	0.0006
MST001-04	0.2610	0.6290	0.5035	0.6449	0.5400	0.6739	0.4052	45.211	0.2216	8.338	1.71E-01	0.9973	0.0006
MST001-05	0.2609	0.6304	0.5054	0.6472	0.5436	0.6766	0.4093	44.1552	0.2214	8.3383	1.76E-01	1.0002	0.0006
MST001-06	0.2601	0.6297	0.5039	0.6446	0.5382	0.6726	0.4022	44.0763	0.2216	8.338	1.69E-01	0.999	0.0006
MST001-07	0.2562	0.6975	0.5667	0.6802	0.5720	0.6430	0.4103	110.439	0.9678	7.94	2.84E-01	1.0005	0.0006
MST001-08	0.2629	0.6355	0.5084	0.6206	0.5073	0.6006	0.3634	213.2237	0.9666	7.9399	1.49E-01	1.0032	0.0006
MST001-09	0.2714	0.5966	0.4744	0.5836	0.4671	0.5681	0.3365	418.636	0.962	7.9402	9.25E-02	1.003	0.0006
MST001-10	0.2644	0.5986	0.4759	0.6108	0.5028	0.6394	0.3779	72.9965	0.2273	8.3378	1.16E-01	1.0025	0.0006
MST001-11	0.2629	0.5949	0.4721	0.6066	0.4981	0.6351	0.3749	72.0147	0.2273	8.3379	1.12E-01	1.0076	0.0007
MST001-12	0.2619	0.5941	0.4713	0.6053	0.4964	0.6338	0.3732	71.5816	0.2278	8.3381	1.09E-01	1.0086	0.0006
MST001-13	0.2698	0.5764	0.4571	0.5859	0.4756	0.6094	0.3587	116.3487	0.2255	8.3378	8.42E-02	1	0.0005
MST002-01	0.2718	0.5172	0.4100	0.5124	0.3971	0.4966	0.2961	1129.223	0.5181	8.3119	4.25E-02	1.0071	0.0006
MST002-02	0.2718	0.5168	0.4097	0.5120	0.3967	0.4957	0.2958	1150.656	0.5211	8.312	4.24E-02	1.0072	0.0006
MST002-03	0.2713	0.5174	0.4101	0.5188	0.4054	0.5147	0.3071	481.3749	0.229	8.3119	4.34E-02	1.0066	0.0005
MST004-01	0.2777	0.5731	0.4554	0.5681	0.4509	0.5716	0.3302	238.9425	0.3968	8.3101	7.15E-02	1.0011	0.0008
MST004-02	0.2764	0.5647	0.4474	0.5613	0.4444	0.5660	0.3274	237.6855	0.3969	8.3099	6.75E-02	1.0013	0.0005
MST004-03	0.2719	0.5661	0.4477	0.5647	0.4498	0.5726	0.3333	238.0412	0.3969	8.31	7.01E-02	1.003	0.0006
MST004-04	0.2560	0.6399	0.5120	0.6426	0.5347	0.6554	0.3944	78.8473	0.4056	8.3098	1.76E-01	1.0024	0.0007
MST004-05	0.2643	0.6361	0.5097	0.6371	0.5261	0.6454	0.3856	78.3251	0.4053	8.3098	1.60E-01	0.9961	0.0006
MST004-06	0.2661	0.6458	0.5195	0.6460	0.5358	0.6542	0.3899	78.5445	0.4052	8.3101	1.93E-01	0.9955	0.0007

Table B.1 (continued)

Experiment	c_k for AOA 3-1	c_k for AOA 3-2	c_k for AOA 3-3	c_k for AOA 4-1	c_k for AOA 4-2	c_k for AOA 4-3	c_k for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
MST004-07	0.2568	0.6987	0.5694	0.7023	0.5979	0.7006	0.4359	49.142	0.3964	8.3098	3.54E-01	0.9966	0.0007
MST004-08	0.2594	0.6820	0.5530	0.6857	0.5793	0.6863	0.4253	49.1257	0.3969	8.3101	2.68E-01	0.9966	0.0006
MST004-09	0.2549	0.6955	0.5653	0.6992	0.5946	0.6980	0.4362	48.9859	0.3972	8.31	3.09E-01	0.9988	0.0007
MST005-01	0.2731	0.5681	0.4497	0.5661	0.4508	0.5738	0.3337	241.4437	0.395	8.31	7.14E-02	0.9967	0.0007
MST005-02	0.2713	0.5613	0.4437	0.5602	0.4451	0.5663	0.3305	238.4842	0.3981	8.3099	6.70E-02	1.0029	0.0007
MST005-03	0.2608	0.6320	0.5054	0.6344	0.5250	0.6444	0.3877	78.8898	0.4066	8.3102	1.55E-01	1.0021	0.0008
MST005-04	0.2589	0.6300	0.5033	0.6321	0.5227	0.6429	0.3860	78.8898	0.4066	8.3102	1.53E-01	0.9992	0.0006
MST005-05	0.2546	0.6448	0.5168	0.6473	0.5405	0.6607	0.3980	78.5768	0.4062	8.3098	1.95E-01	0.9892	0.0007
MST005-06	0.2485	0.6950	0.5647	0.7008	0.6000	0.7052	0.4431	49.0373	0.3966	8.3099	3.56E-01	0.9875	0.0007
MST005-07	0.2556	0.6763	0.5471	0.6812	0.5762	0.6842	0.4266	49.0069	0.3964	8.3099	2.54E-01	0.9976	0.0006
NSE55T4-01	0.2584	0.6117	0.4875	0.6337	0.5273	0.6735	0.3962	30.6	0.146	7.97	1.43E-01	1.0179	0.0006
NSE55T4-02	0.2589	0.6145	0.4901	0.6369	0.5313	0.6768	0.4005	30.6	0.146	7.97	1.46E-01	1.0187	0.0006
NSE55T4-03	0.2586	0.6148	0.4903	0.6375	0.5321	0.6780	0.4013	30.6	0.146	7.97	1.47E-01	1.0175	0.0007
NSE55T4-04	0.2585	0.6153	0.4909	0.6385	0.5338	0.6797	0.4036	30.6	0.146	7.97	1.49E-01	1.0182	0.0006
NSE55T4-05	0.2585	0.6162	0.4917	0.6396	0.5352	0.6810	0.4048	30.6	0.146	7.97	1.50E-01	1.0176	0.0006
NSE55T4-06	0.2578	0.6165	0.4919	0.6402	0.5360	0.6824	0.4056	30.6	0.146	7.97	1.51E-01	1.0174	0.0006
NSE55T4-07	0.2592	0.6166	0.4920	0.6398	0.5350	0.6805	0.4039	30.6	0.146	7.97	1.51E-01	1.0208	0.0006
NSE55T4-08	0.2591	0.6182	0.4936	0.6421	0.5383	0.6836	0.4079	30.6	0.146	7.97	1.53E-01	1.0181	0.0007
NSE55T4-09	0.2601	0.6111	0.4871	0.6331	0.5266	0.6726	0.3963	30.6	0.146	7.97	1.43E-01	1.0186	0.0005
NSE55T4-10	0.2596	0.6121	0.4880	0.6341	0.5279	0.6734	0.3975	30.6	0.146	7.97	1.43E-01	1.0184	0.0006
NSE55T4-11	0.2589	0.6120	0.4878	0.6341	0.5282	0.6741	0.3981	30.6	0.146	7.97	1.43E-01	1.0193	0.0006
NSE55T4-12	0.2574	0.6139	0.4894	0.6357	0.5300	0.6753	0.3994	30.6	0.146	7.97	1.43E-01	1.0192	0.0006
NSE55T4-13	0.2603	0.6118	0.4877	0.6344	0.5285	0.6749	0.3980	30.6	0.146	7.97	1.46E-01	1.0188	0.0006
NSE55T4-14	0.2599	0.6169	0.4924	0.6403	0.5353	0.6807	0.4045	30.6	0.146	7.97	1.51E-01	1.0213	0.0006
NSE55T4-15	0.2591	0.6160	0.4916	0.6392	0.5342	0.6798	0.4030	30.6	0.146	7.97	1.50E-01	1.0211	0.0006
NSE55T4-16	0.2588	0.6154	0.4909	0.6384	0.5333	0.6790	0.4026	30.6	0.146	7.97	1.49E-01	1.0201	0.0006
NSE55T4-17	0.2601	0.6187	0.4941	0.6429	0.5395	0.6846	0.4097	30.6	0.146	7.97	1.54E-01	1.0182	0.0005
NSE55T4-18	0.2586	0.6188	0.4941	0.6434	0.5403	0.6861	0.4105	30.6	0.146	7.97	1.55E-01	1.0161	0.0006
NSE55T4-19	0.2584	0.6191	0.4944	0.6438	0.5411	0.6870	0.4114	30.6	0.146	7.97	1.56E-01	1.0154	0.0006

Table B.1 (continued)

Experiment	c_k for AOA 3-1	c_k for AOA 3-2	c_k for AOA 3-3	c_k for AOA 4-1	c_k for AOA 4-2	c_k for AOA 4-3	c_k for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
NSE55T4-20	0.2608	0.6200	0.4953	0.6442	0.5405	0.6851	0.4098	30.6	0.146	7.97	1.58E-01	1.0213	0.0006
NSE55T4-21	0.2570	0.6130	0.4884	0.6355	0.5299	0.6766	0.3994	30.6	0.146	7.97	1.46E-01	1.0528	0.0006
NSE55T4-22	0.2577	0.6120	0.4877	0.6347	0.5296	0.6759	0.4006	30.6	0.146	7.97	1.45E-01	1.0463	0.0006
NSE55T5-01	0.3630	0.9453	0.8744	0.9819	0.9345	0.8423	0.7358	2.8	0.303	11.5	3.97E+01	1.0058	0.0005
NSE55T5-02	0.3659	0.9437	0.8728	0.9811	0.9334	0.8422	0.7349	2.8	0.303	11.5	3.97E+01	1.0028	0.0005
NSE55T5-03	0.3667	0.9424	0.8717	0.9803	0.9341	0.8416	0.7388	2.8	0.303	11.5	4.00E+01	1.0049	0.0005
NSE55T5-04	0.3662	0.9422	0.8720	0.9806	0.9356	0.8419	0.7420	2.8	0.303	11.5	4.10E+01	1.0048	0.0005
NSE55T5-05	0.3671	0.9438	0.8737	0.9817	0.9350	0.8417	0.7372	2.8	0.303	11.5	4.03E+01	1.002	0.0005
NSE55T5-06	0.3668	0.9422	0.8726	0.9821	0.9354	0.8405	0.7354	2.8	0.303	11.5	4.14E+01	1.0045	0.0005
NSE55T5-07	0.3518	0.9457	0.8737	0.9833	0.9371	0.8442	0.7363	2.8	0.303	11.5	4.39E+01	1.0042	0.0005
NSE55T5-08	0.3657	0.9445	0.8736	0.9809	0.9334	0.8399	0.7357	2.8	0.303	11.5	3.93E+01	1.0026	0.0006
NSE55T5-09	0.3832	0.9370	0.8696	0.9783	0.9305	0.8359	0.7332	2.8	0.303	11.5	3.88E+01	1.0023	0.0005
NSE55T5-10	0.3577	0.9451	0.8728	0.9822	0.9336	0.8432	0.7316	2.8	0.303	11.5	3.85E+01	1.0036	0.0004
PCI001-01	0.3014	0.8158	0.7637	0.8493	0.8388	0.6325	0.6818	0.37	1	5.3	3.08E+02	0.9988	0.0001
PCM001-01	0.6698	0.5606	0.7021	0.4788	0.4471	0.2571	0.3256	0.04	1	18.35	9.57E+05	1.0261	0.0007
PCM001-02	0.4164	0.9773	0.9647	0.9329	0.8974	0.6574	0.6887	5	1	11.46	1.73E+03	1.0198	0.0007
PCM001-03	0.2535	0.9670	0.8736	0.9241	0.8615	0.7241	0.6332	15	1	2.2	3.26E+01	1.0168	0.0008
PCM001-04	0.2681	0.9707	0.8810	0.9359	0.8784	0.7286	0.6530	15	1	8.06	3.95E+01	0.9878	0.0007
PCM001-05	0.2561	0.8181	0.6919	0.7992	0.7112	0.7066	0.5182	49.6	1	18.35	1.54E+00	1.0087	0.0007
PCM002-01	0.8177	0.7787	0.9080	0.7275	0.6915	0.4588	0.5665	0.04	1	18.35	4.92E+03	1.0322	0.0007
PCM002-02	0.8343	0.7614	0.8954	0.7098	0.6719	0.4451	0.5527	0.04	1	18.35	4.21E+03	1.0308	0.0006
PCM002-03	0.8083	0.7929	0.9152	0.7435	0.7066	0.4755	0.5781	0.04	1	18.35	3.51E+03	1.0262	0.0006
PCM002-04	0.8077	0.7930	0.9123	0.7451	0.7064	0.4804	0.5782	0.04	1	18.35	2.57E+03	1.0197	0.0006
PCM002-05	0.7875	0.8178	0.9263	0.7707	0.7307	0.5044	0.5945	0.04	1	18.35	1.87E+03	1.0171	0.0006
PCM002-06	0.4413	0.9893	0.9537	0.9484	0.8898	0.6987	0.6800	5	1	11.46	9.25E+01	1.0234	0.0006
PCM002-07	0.3385	0.9880	0.9339	0.9470	0.8955	0.6974	0.6769	5	1	11.46	8.49E+01	1.022	0.0006
PCM002-08	0.4344	0.9875	0.9483	0.9447	0.8828	0.7011	0.6722	5	1	11.46	6.80E+01	1.0212	0.0006
PCM002-09	0.4917	0.9779	0.9486	0.9451	0.8841	0.7042	0.6831	5	1	11.46	5.68E+01	1.0218	0.0005
PCM002-10	0.2557	0.9384	0.8290	0.8984	0.8173	0.7271	0.5973	15	1	2.2	4.14E+00	1.0306	0.0006

Table B.1 (continued)

Experiment	c_k for AOA 3-1	c_k for AOA 3-2	c_k for AOA 3-3	c_k for AOA 4-1	c_k for AOA 4-2	c_k for AOA 4-3	c_k for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
PCM002-11	0.2514	0.9390	0.8293	0.8977	0.8165	0.7256	0.5957	15	1	2.2	4.55E+00	1.028	0.0006
PCM002-12	0.2527	0.9419	0.8331	0.9005	0.8203	0.7265	0.5988	15	1	2.2	5.13E+00	1.0273	0.0006
PCM002-13	0.4113	0.8774	0.7905	0.8454	0.7487	0.7088	0.5562	15	1	2.2	5.46E+00	1.0256	0.0006
PCM002-14	0.2554	0.9457	0.8378	0.9045	0.8251	0.7273	0.6031	15	1	2.2	5.60E+00	1.0295	0.0006
PCM002-15	0.2661	0.9446	0.8375	0.9053	0.8250	0.7295	0.6046	15	1	2.2	5.56E+00	1.0283	0.0006
PCM002-16	0.2530	0.9444	0.8358	0.9023	0.8221	0.7258	0.5999	15	1	2.2	5.15E+00	1.0235	0.0007
PCM002-17	0.2962	0.9426	0.8393	0.9108	0.8315	0.7363	0.6162	15	1	2.2	4.93E+00	1.0073	0.0007
PCM002-18	0.2959	0.9491	0.8471	0.9164	0.8387	0.7366	0.6216	15	1	2.2	6.19E+00	1.0102	0.0006
PCM002-19	0.2846	0.9497	0.8464	0.9149	0.8375	0.7349	0.6187	15	1	2.2	6.47E+00	1.0088	0.0006
PCM002-20	0.2966	0.9505	0.8489	0.9176	0.8403	0.7366	0.6227	15	1	2.2	6.65E+00	1.0087	0.0005
PCM002-21	0.2703	0.9541	0.8495	0.9198	0.8452	0.7352	0.6247	15	1	2.2	6.64E+00	1.0101	0.0006
PCM002-22	0.2886	0.9511	0.8483	0.9182	0.8415	0.7365	0.6233	15	1	2.2	6.45E+00	1.0143	0.0007
PCM002-23	0.2634	0.7924	0.6641	0.7735	0.6762	0.6908	0.4921	49.6	1	18.35	6.84E-01	1.0087	0.0006
PCM002-24	0.2633	0.7930	0.6647	0.7741	0.6769	0.6911	0.4926	49.6	1	18.35	6.97E-01	1.0096	0.0006
PCM002-25	0.2640	0.7935	0.6653	0.7747	0.6776	0.6916	0.4933	49.6	1	18.35	7.05E-01	1.0096	0.0006
PCM002-26	0.2574	0.7935	0.6645	0.7730	0.6758	0.6903	0.4903	49.6	1	18.35	7.13E-01	1.0113	0.0006
PCM002-27	0.2674	0.7934	0.6658	0.7754	0.6786	0.6922	0.4948	49.6	1	18.35	7.21E-01	1.011	0.0006
PCM002-28	0.2556	0.7937	0.6645	0.7727	0.6756	0.6902	0.4898	49.6	1	18.35	7.26E-01	1.0099	0.0005
PCM002-29	0.2593	0.7923	0.6635	0.7719	0.6745	0.6897	0.4895	49.6	1	18.35	7.36E-01	1.0117	0.0006
PMF001-01	0.8602	0.5766	0.7739	0.5240	0.5176	0.2754	0.4394	0	1	4.7	1.24E+06	0.9949	0.0007
PMF002-01	0.8488	0.5675	0.7621	0.5166	0.5105	0.2714	0.4345	0	1	20.1	1.26E+06	0.9964	0.0005
PMF003-01	0.8617	0.5761	0.7736	0.5232	0.5164	0.2748	0.4381	0	1	5.97	1.24E+06	0.9937	0.0006
PMF003-02	0.8621	0.5941	0.7875	0.5415	0.5328	0.2906	0.4508	0	1	5.97	6.90E+05	0.9935	0.0007
PMF003-03	0.8612	0.5761	0.7736	0.5233	0.5165	0.2748	0.4382	0	1	5.97	1.24E+06	0.9879	0.0006
PMF003-04	0.8596	0.6007	0.7914	0.5453	0.5339	0.2948	0.4484	0	1	5.97	6.24E+05	0.9926	0.0006
PMF003-05	0.8578	0.5702	0.7659	0.5141	0.5046	0.2697	0.4245	0	1	5.97	1.24E+06	0.9908	0.0007
PMF016-01	0.8668	0.7258	0.8772	0.6777	0.6470	0.4190	0.5359	0	1	5.97	1.17E+04	1.0118	0.0006
PMF016-02	0.8553	0.7254	0.8764	0.6749	0.6437	0.4157	0.5321	0	1	5.97	8.61E+03	1.0003	0.0006
PMF016-03	0.8597	0.7124	0.8665	0.6611	0.6296	0.4051	0.5212	0	1	5.97	8.34E+03	0.9995	0.0007

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Table B.1 (continued)

Experiment	c_k for AOA 3-1	c_k for AOA 3-2	c_k for AOA 3-3	c_k for AOA 4-1	c_k for AOA 4-2	c_k for AOA 4-3	c_k for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
PMF016-04	0.8589	0.7250	0.8761	0.6749	0.6433	0.4169	0.5319	0	1	5.97	8.01E+03	0.9982	0.0007
PMF016-05	0.8715	0.7193	0.8710	0.6735	0.6426	0.4182	0.5345	0	1	5.97	7.93E+03	0.9965	0.0006
PMF016-06	0.8425	0.7377	0.8850	0.6833	0.6502	0.4227	0.5334	0	1	5.97	7.78E+03	1.0003	0.0007
PMF017-01	0.8588	0.6077	0.7987	0.5555	0.5473	0.3004	0.4632	0	1	5.97	7.82E+05	0.9901	0.0007
PMF017-02	0.8550	0.6375	0.8210	0.5864	0.5761	0.3267	0.4857	0	1	5.97	4.05E+05	0.9932	0.0007
PMF017-03	0.8541	0.6542	0.8328	0.6030	0.5904	0.3420	0.4958	0	1	5.97	2.30E+05	0.994	0.0008
PMF017-04	0.8507	0.6420	0.8244	0.5917	0.5824	0.3300	0.4921	0	1	5.97	4.58E+05	0.991	0.0006
PMF017-05	0.8405	0.6987	0.8639	0.6462	0.6287	0.3796	0.5223	0	1	5.97	9.39E+04	1.002	0.0006
PMF033-01	0.8288	0.6137	0.7878	0.5994	0.6017	0.3479	0.5240	0	1	5.83	4.02E+05	1.0066	0.0005
PMF037-01	0.8584	0.6620	0.8379	0.6101	0.5941	0.3495	0.4974	0	1	5.97	1.48E+05	0.9973	0.0006
PMF037-05	0.8497	0.7034	0.8664	0.6509	0.6291	0.3861	0.5222	0	1	5.97	5.12E+04	0.9977	0.0006
PMF037-07	0.8614	0.7066	0.8685	0.6571	0.6339	0.3941	0.5277	0	1	5.97	3.30E+04	0.9984	0.0006
PMF037-10	0.8577	0.7001	0.8596	0.6486	0.6212	0.3815	0.5177	0	1	5.97	2.61E+04	0.9993	0.0006
PMF037-12	0.8597	0.7081	0.8685	0.6566	0.6310	0.3954	0.5231	0	1	5.97	2.35E+04	1.0009	0.0006
PMF037-15	0.8623	0.7154	0.8729	0.6651	0.6379	0.4038	0.5293	0	1	5.97	1.82E+04	0.9985	0.0005
PMF037-16	0.8625	0.6991	0.8622	0.6490	0.6249	0.3880	0.5205	0	1	5.97	2.84E+04	0.9996	0.0006
PU-15-1	0.3183	0.8787	0.7860	0.9493	0.9086	0.9036	0.7420	2.86	0.15	11.5	1.51E+01	0.9811	0.0003
PU-29-1	0.3677	0.9456	0.8755	0.9836	0.9340	0.8408	0.7303	2.77	0.29	11.5	4.14E+01	0.9941	0.0003
PU-29-2	0.3686	0.9450	0.8752	0.9837	0.9339	0.8404	0.7293	2.77	0.29	11.5	4.03E+01	0.9931	0.0005
PU-29-3	0.3669	0.9451	0.8748	0.9829	0.9342	0.8416	0.7330	2.77	0.29	11.5	4.07E+01	1.0022	0.0005
PU-29-4	0.3667	0.9453	0.8744	0.9824	0.9324	0.8416	0.7306	2.77	0.29	11.5	3.78E+01	0.9932	0.0004
PU-29-5	0.3709	0.9443	0.8740	0.9822	0.9322	0.8405	0.7306	2.77	0.29	11.5	3.77E+01	0.9937	0.0003
PU-29-6	0.3727	0.9432	0.8723	0.9803	0.9299	0.8405	0.7311	2.77	0.29	11.5	3.67E+01	0.9931	0.0003
PU-29-7	0.3660	0.9448	0.8727	0.9808	0.9303	0.8425	0.7305	2.77	0.29	11.5	3.48E+01	0.9944	0.0005
PU-29-8	0.3708	0.9437	0.8728	0.9805	0.9311	0.8414	0.7330	2.77	0.29	11.5	3.44E+01	0.9951	0.0005
PU-29-9	0.3702	0.9431	0.8716	0.9796	0.9298	0.8413	0.7325	2.77	0.29	11.5	3.46E+01	0.9987	0.0005
PU-8-1	0.2533	0.6815	0.5591	0.7474	0.6645	0.8178	0.5184	7.33	0.08	11.5	6.45E-01	1.005	0.0006
PU-8-2	0.2544	0.6818	0.5595	0.7476	0.6650	0.8179	0.5197	7.33	0.08	11.5	6.41E-01	1.0036	0.0005

Table B.1 (continued)

Experiment	c_k for AOA 3-1	c_k for AOA 3-2	c_k for AOA 3-3	c_k for AOA 4-1	c_k for AOA 4-2	c_k for AOA 4-3	c_k for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
PU-8-3	0.2550	0.6820	0.5596	0.7474	0.6652	0.8180	0.5217	7.33	0.08	11.5	6.38E-01	1.0059	0.0006
PU-8-4	0.2537	0.6815	0.5590	0.7469	0.6646	0.8180	0.5207	7.33	0.08	11.5	6.30E-01	1.0053	0.0006

Table B.2. Tabulated E_{sum} values and calculated parameters for design systems and benchmark experiments

Experiment	E_{sum} for AOA 3-1	E_{sum} for AOA 3-2	E_{sum} for AOA 3-3	E_{sum} for AOA 4-1	E_{sum} for AOA 4-2	E_{sum} for AOA 4-3	E_{sum} for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
BNWL2129T3-01	0.1959	0.5825	0.4255	0.5259	0.2080	0.1959	0.1230	30.6	0.146	7.97	1.44E-01	1.0184	0.0005
BNWL2129T3-02	0.1938	0.5796	0.4224	0.5255	0.2111	0.1987	0.1261	30.6	0.146	7.97	1.46E-01	1.0195	0.0006
BNWL2129T3-03	0.1890	0.5732	0.4124	0.5233	0.2069	0.2040	0.1275	30.6	0.146	7.97	1.47E-01	1.0187	0.0005
BNWL2129T3-04	0.1861	0.5694	0.4074	0.5191	0.2060	0.2057	0.1265	30.6	0.146	7.97	1.49E-01	1.021	0.0006
BNWL2129T3-05	0.1857	0.5705	0.4107	0.5240	0.2152	0.2072	0.1320	30.6	0.146	7.97	1.50E-01	1.0219	0.0006
BNWL2129T3-06	0.1844	0.5684	0.4083	0.5205	0.2138	0.2072	0.1294	30.6	0.146	7.97	1.51E-01	1.0213	0.0006
BNWL2129T3-07	0.1828	0.5659	0.4054	0.5181	0.2125	0.2074	0.1296	30.6	0.146	7.97	1.52E-01	1.0206	0.0006
BNWL2129T3-08	0.1853	0.5672	0.4053	0.5198	0.2089	0.2083	0.1286	30.6	0.146	7.97	1.53E-01	1.0189	0.0005
BNWL2129T3-09	0.1849	0.5663	0.4045	0.5196	0.2094	0.2089	0.1299	30.6	0.146	7.97	1.54E-01	1.0179	0.0006
BNWL2129T3-10	0.1813	0.5610	0.3992	0.5154	0.2102	0.2101	0.1296	30.6	0.146	7.97	1.54E-01	1.0199	0.0006
BNWL2129T3-11	0.1831	0.5651	0.4054	0.5196	0.2159	0.2088	0.1308	30.6	0.146	7.97	1.55E-01	1.0197	0.0006
BNWL2129T3-12	0.1810	0.5611	0.3998	0.5168	0.2120	0.2109	0.1314	30.6	0.146	7.97	1.55E-01	1.0178	0.0006
BNWL2129T3-13A	0.1850	0.5652	0.4035	0.5188	0.2086	0.2083	0.1297	30.6	0.146	7.97	1.54E-01	1.0179	0.0006
BNWL2129T3-14	0.1818	0.5615	0.3990	0.5171	0.2092	0.2108	0.1309	30.6	0.146	7.97	1.55E-01	1.0176	0.0005
BNWL2129T3-15	0.1816	0.5617	0.4010	0.5177	0.2132	0.2103	0.1319	30.6	0.146	7.97	1.55E-01	1.0175	0.0007
BNWL2129T3-16	0.1883	0.5712	0.4129	0.5319	0.2224	0.2071	0.1408	30.6	0.146	7.97	1.68E-01	1.0195	0.0006
BNWL2129T3-17	0.1858	0.5679	0.4099	0.5424	0.2453	0.2175	0.1628	30.6	0.146	7.97	2.04E-01	1.0195	0.0006
BNWL2129T3-18	0.1827	0.5592	0.4028	0.5451	0.2588	0.2233	0.1852	30.6	0.146	7.97	2.46E-01	1.0181	0.0006
BNWL2129T3-19	0.1803	0.5586	0.3999	0.5440	0.2599	0.2258	0.1894	30.6	0.146	7.97	2.57E-01	1.0173	0.0005
BNWL2129T3-20	0.1811	0.5586	0.3972	0.5140	0.2087	0.2095	0.1293	30.6	0.146	7.97	1.54E-01	1.0239	0.0006
BNWL2129T3-21	0.1799	0.5549	0.3947	0.5103	0.2079	0.2078	0.1292	30.6	0.146	7.97	1.55E-01	1.0234	0.0006
BNWL2129T3-22	0.1793	0.5551	0.3930	0.5125	0.2065	0.2110	0.1305	30.6	0.146	7.97	1.56E-01	1.0216	0.0006
BNWL2129T3-23	0.1805	0.5579	0.3973	0.5136	0.2087	0.2091	0.1300	30.6	0.146	7.97	1.55E-01	1.0207	0.0006
BNWL2129T3-24	0.1788	0.5563	0.3953	0.5133	0.2098	0.2105	0.1293	30.6	0.146	7.97	1.56E-01	1.0457	0.0007
BNWL2129T3-25	0.1861	0.5676	0.4055	0.5219	0.2102	0.2099	0.1315	30.6	0.146	7.97	1.53E-01	0.9862	0.0007
BNWL2129T3-26	0.1865	0.5678	0.4085	0.5217	0.2149	0.2076	0.1332	30.6	0.146	7.97	1.53E-01	0.9775	0.0007
BNWL2129T3-27	0.1721	0.5831	0.4220	0.5314	0.2089	0.1989	0.1279	30.6	0.146	7.97	1.44E-01	1.0194	0.0006
BNWL2129T3-28	0.1971	0.5819	0.4223	0.5283	0.2061	0.1998	0.1265	30.6	0.146	7.97	1.43E-01	1.021	0.0006
BNWL2129T3-29	0.1944	0.5810	0.4236	0.5269	0.2096	0.1982	0.1260	30.6	0.146	7.97	1.43E-01	1.0203	0.0006

Table B.2 (continued)

Experiment	E_{sum} for AOA 3-1	E_{sum} for AOA 3-2	E_{sum} for AOA 3-3	E_{sum} for AOA 4-1	E_{sum} for AOA 4-2	E_{sum} for AOA 4-3	E_{sum} for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
BNWL2129T3-30	0.1946	0.5810	0.4222	0.5277	0.2072	0.1996	0.1264	30.6	0.146	7.97	1.43E-01	1.0214	0.0006
BNWL2129T3-31	0.1933	0.5782	0.4193	0.5274	0.2093	0.2017	0.1284	30.6	0.146	7.97	1.43E-01	1.0216	0.0006
BNWL2129T4-01	0.2542	0.7714	0.6445	0.8006	0.5546	0.2656	0.3972	7.13	0.28	10.95	6.13E+00	1.0184	0.0006
BNWL2129T4-02	0.2376	0.7440	0.6062	0.7687	0.5190	0.2699	0.3749	7.64	0.28	10.89	4.51E+00	1.0178	0.0006
BNWL2129T4-03	0.2280	0.7087	0.5659	0.7204	0.4613	0.2583	0.3255	8.08	0.27	10.83	3.44E+00	1.018	0.0007
BNWL2129T4-04	0.2419	0.7504	0.6117	0.7699	0.5141	0.2666	0.3697	7.51	0.28	10.9	5.08E+00	1.0182	0.0005
BNWL2129T4-05	0.2268	0.7008	0.5555	0.7032	0.4333	0.2522	0.3043	8.29	0.27	10.8	3.22E+00	1.0183	0.0006
BNWL2129T4-06	0.2187	0.6654	0.5209	0.6542	0.3795	0.2351	0.2573	8.81	0.27	10.74	2.24E+00	1.018	0.0005
BNWL2129T4-07	0.2455	0.7503	0.6123	0.7693	0.5013	0.2613	0.3643	7.57	0.28	10.89	4.91E+00	1.0165	0.0005
BNWL2129T4-08	0.2260	0.6857	0.5464	0.6915	0.4231	0.2453	0.2974	8.71	0.27	10.75	2.40E+00	1.0186	0.0005
BNWL2129T4-09	0.2407	0.7517	0.6164	0.7802	0.5315	0.2667	0.3849	7.39	0.28	10.92	5.78E+00	1.0187	0.0006
BNWL2129T4-10	0.2345	0.7308	0.5889	0.7592	0.4965	0.2653	0.3703	7.72	0.28	10.88	5.24E+00	1.0159	0.0006
BNWL2129T4-11	0.2179	0.6844	0.5388	0.7089	0.4642	0.2649	0.3434	8.52	0.27	10.77	3.48E+00	1.0166	0.0005
BNWL2129T4-12	0.2333	0.7034	0.5758	0.7265	0.4691	0.2430	0.3321	8.09	0.27	10.83	3.84E+00	1.02	0.0005
BNWL2129T4-13	0.2226	0.6773	0.5323	0.6741	0.4001	0.2437	0.2805	8.79	0.27	10.74	2.47E+00	1.0214	0.0007
BNWL2129T4-14	0.2134	0.6489	0.4950	0.6280	0.3304	0.2335	0.2250	9.37	0.27	10.67	1.51E+00	1.0196	0.0006
BNWL2129T4-15	0.2382	0.7363	0.6030	0.7605	0.5120	0.2644	0.3698	7.51	0.28	10.9	5.08E+00	1.0161	0.0005
BNWL2129T4-16	0.2441	0.7529	0.6199	0.7789	0.5268	0.2652	0.3800	7.37	0.28	10.92	5.24E+00	1.0178	0.0006
BNWL2129T4-17	0.2434	0.7482	0.6110	0.7616	0.4991	0.2590	0.3524	7.68	0.28	10.88	4.28E+00	1.0172	0.0005
BNWL2129T4-18	0.2409	0.7251	0.5851	0.7315	0.4527	0.2486	0.3203	7.91	0.27	10.85	3.58E+00	1.0171	0.0005
BNWL2129T4-19	0.2473	0.7274	0.5990	0.7454	0.4803	0.2442	0.3375	7.79	0.27	10.87	4.05E+00	1.0181	0.0006
LCT049-01	0.0573	0.1832	0.1594	0.3519	0.4058	0.1724	0.3806	2.0124	0	0	2.19E+00	0.9902	0.0007
LCT049-02	0.0607	0.1905	0.1667	0.3587	0.4109	0.1723	0.3768	2.0124	0	0	2.21E+00	0.9912	0.0006
LCT049-03	0.0598	0.1901	0.1655	0.3583	0.4107	0.1718	0.3783	2.0124	0	0	2.34E+00	0.9918	0.0005
LCT049-04	0.0689	0.2074	0.1787	0.3778	0.4134	0.1755	0.3883	2.0124	0	0	2.36E+00	0.9957	0.0005
LCT049-05	0.0617	0.1991	0.1674	0.3292	0.3489	0.1578	0.3098	2.5164	0	0	1.23E+00	0.9902	0.0005
LCT049-06	0.0742	0.2298	0.1953	0.3549	0.3640	0.1583	0.3083	2.5164	0	0	1.25E+00	0.9919	0.0006
LCT049-07	0.0737	0.2301	0.1945	0.3543	0.3629	0.1580	0.3080	2.5164	0	0	1.20E+00	0.9897	0.0006
LCT049-08	0.0674	0.2131	0.1819	0.3447	0.3650	0.1591	0.3193	2.5164	0	0	1.29E+00	0.9906	0.0006
LCT049-09	0.0784	0.2457	0.2061	0.3423	0.3303	0.1472	0.2679	3.0067	0	0	7.94E-01	0.9901	0.0005

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Table B.2 (continued)

Experiment	E_{sum} for AOA 3-1	E_{sum} for AOA 3-2	E_{sum} for AOA 3-3	E_{sum} for AOA 4-1	E_{sum} for AOA 4-2	E_{sum} for AOA 4-3	E_{sum} for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
LCT049-10	0.0823	0.2545	0.2131	0.3499	0.3325	0.1481	0.2655	3.0067	0	0	8.00E-01	0.9912	0.0007
LCT049-11	0.0806	0.2500	0.2090	0.3459	0.3296	0.1476	0.2654	3.0067	0	0	7.95E-01	0.9899	0.0006
LCT049-12	0.0779	0.2436	0.2043	0.3435	0.3336	0.1492	0.2735	3.0067	0	0	8.39E-01	0.9898	0.0006
LCT049-13	0.0770	0.2374	0.2027	0.3709	0.3859	0.1637	0.3259	3.0067	0	0	1.53E+00	0.9891	0.0006
LCT049-14	0.0745	0.2309	0.1991	0.3709	0.3946	0.1641	0.3407	3.0067	0	0	1.53E+00	0.9898	0.0006
LCT049-15	0.0713	0.2222	0.1893	0.3580	0.3766	0.1633	0.3235	3.0067	0	0	1.54E+00	0.9906	0.0007
LCT049-16	0.0730	0.2277	0.1941	0.3536	0.3664	0.1581	0.3120	3.0067	0	0	1.19E+00	0.9907	0.0006
LCT049-17	0.0708	0.2220	0.1897	0.3502	0.3653	0.1599	0.3170	3.0067	0	0	1.28E+00	0.9905	0.0005
LCT049-18	0.0567	0.1834	0.1559	0.3145	0.3392	0.1540	0.3086	3.0067	0	0	1.09E+00	0.9943	0.0006
MCT001-01	0.2374	0.7147	0.5573	0.6813	0.3751	0.2331	0.2289	3.3346	0.2237	11.5414	1.61E-03	1.0022	0.0005
MCT001-02	0.2455	0.6700	0.5184	0.6003	0.2514	0.1874	0.1471	6.8576	0.2237	11.5414	4.76E-04	1.0012	0.0006
MCT001-03	0.1424	0.5252	0.3893	0.4837	0.1664	0.1541	0.1178	10.8808	0.2237	11.5414	2.91E-04	1.0025	0.0007
MCT001-04	0.1656	0.4460	0.3323	0.4066	0.0915	0.1138	0.0819	17.5335	0.2237	11.5414	2.11E-04	1.004	0.0006
MCT002-01	0.1768	0.5391	0.3970	0.6065	0.3786	0.2633	0.2828	1.1946	0.0204	7.7593	5.79E-01	0.9934	0.0006
MCT002-02	0.1559	0.4942	0.3540	0.5826	0.3885	0.2800	0.2993	1.1946	0.0204	7.7593	7.73E-01	0.9958	0.0006
MCT002-03	0.1991	0.5703	0.4175	0.5531	0.2273	0.2014	0.1651	2.5249	0.0204	7.7593	1.93E-01	0.999	0.0006
MCT002-04	0.1461	0.4591	0.3165	0.4818	0.2287	0.2203	0.1828	2.5249	0.0204	7.7593	2.82E-01	1.005	0.0007
MCT002-05	0.2002	0.5666	0.4136	0.5315	0.1793	0.1791	0.1377	3.641	0.0204	7.7593	1.38E-01	1.004	0.0006
MCT002-06	0.1476	0.4526	0.3100	0.4560	0.1752	0.1947	0.1519	3.641	0.0204	7.7593	1.83E-01	1.0063	0.0006
MCT003-01	0.2284	0.6711	0.5195	0.6971	0.4115	0.2494	0.2759	1.6814	0.0659	8.5826	9.06E-01	0.9931	0.0006
MCT003-02	0.2340	0.6672	0.5136	0.6676	0.3493	0.2288	0.2291	2.1645	0.0659	8.5826	5.50E-01	0.9942	0.0007
MCT003-03	0.2179	0.6468	0.4905	0.6525	0.3688	0.2425	0.2368	2.1645	0.0659	8.5826	6.56E-01	0.9939	0.0006
MCT003-04	0.2303	0.6407	0.4857	0.5856	0.2194	0.1827	0.1410	4.7057	0.0659	8.5826	1.88E-01	0.9984	0.0007
MCT003-05	0.2296	0.6340	0.4802	0.5743	0.1988	0.1715	0.1316	5.672	0.0659	8.5826	1.56E-01	0.9987	0.0006
MCT003-06	0.2169	0.6037	0.4521	0.5339	0.1398	0.1487	0.1079	10.7543	0.0659	8.5826	1.01E-01	1.0023	0.0006
MCT004-01	0.1909	0.5521	0.3974	0.5247	0.2051	0.1988	0.1448	2.4201	0.03	22.0825	1.46E-01	0.9936	0.0006
MCT004-02	0.1914	0.5526	0.3986	0.5235	0.2039	0.1974	0.1421	2.4201	0.0299	22.1504	1.45E-01	0.9951	0.0005
MCT004-03	0.1895	0.5485	0.3947	0.5202	0.2028	0.1975	0.1418	2.4201	0.028	23.7291	1.45E-01	0.9956	0.0006

Table B.2 (continued)

Experiment	E_{sum} for AOA 3-1	E_{sum} for AOA 3-2	E_{sum} for AOA 3-3	E_{sum} for AOA 4-1	E_{sum} for AOA 4-2	E_{sum} for AOA 4-3	E_{sum} for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
MCT004-04	0.1924	0.5517	0.3969	0.5127	0.1787	0.1855	0.1291	2.9761	0.03	22.078	1.21E-01	0.9951	0.0007
MCT004-05	0.1932	0.5527	0.3978	0.5151	0.1787	0.1862	0.1303	2.9761	0.0299	22.1521	1.20E-01	0.9962	0.0006
MCT004-06	0.1909	0.5476	0.3935	0.5098	0.1771	0.1859	0.1288	2.9761	0.0298	22.289	1.19E-01	0.998	0.0006
MCT004-07	0.1901	0.5415	0.3894	0.4941	0.1419	0.1657	0.1135	4.2387	0.03	22.0708	9.34E-02	0.9983	0.0006
MCT004-08	0.1898	0.5419	0.3888	0.4948	0.1411	0.1670	0.1138	4.2387	0.0299	22.1533	9.31E-02	0.9992	0.0006
MCT004-09	0.1884	0.5374	0.3850	0.4913	0.1405	0.1666	0.1135	4.2387	0.0298	22.2246	9.28E-02	0.9995	0.0006
MCT004-10	0.1842	0.5264	0.3767	0.4790	0.1160	0.1532	0.1069	5.5521	0.03	22.0739	8.05E-02	0.9991	0.0007
MCT004-11	0.1842	0.5237	0.3744	0.4769	0.1144	0.1527	0.1057	5.5521	0.0299	22.155	8.02E-02	1.0004	0.0006
MCT005-01	0.2123	0.4836	0.3705	0.5378	0.2443	0.1555	0.1934	2.2187	0.0399	18.2054	3.82E-04	0.9964	0.0005
MCT005-02	0.2236	0.5001	0.3885	0.5307	0.2101	0.1576	0.1647	2.8531	0.0399	18.2054	2.54E-04	0.9954	0.0005
MCT005-03	0.2252	0.4735	0.3706	0.4946	0.1600	0.1473	0.1344	3.9116	0.0399	18.2054	1.73E-04	1.004	0.0006
MCT005-04	0.2234	0.4582	0.3579	0.4785	0.1332	0.1277	0.1232	4.8202	0.0399	18.2054	1.39E-04	1.028	0.0006
MCT005-05	0.2182	0.4542	0.3547	0.4674	0.1024	0.1159	0.1127	7.558	0.0399	18.2054	1.03E-04	1.0068	0.0006
MCT005-06	0.2007	0.3141	0.2570	0.3622	0.0500	0.0732	0.0912	10.4047	0.0399	18.2054	8.80E-05	1.0058	0.0004
MCT005-07	0.1966	0.3965	0.3097	0.4253	0.0647	0.0975	0.1060	11.8748	0.0399	18.2054	8.30E-05	1.0068	0.0006
MCT008-01	0.1659	0.4967	0.3503	0.5634	0.3040	0.2537	0.2496	1.7672	0.02	23.5804	3.99E-01	0.9921	0.0005
MCT008-02	0.1756	0.5179	0.3657	0.5270	0.2162	0.2106	0.1771	2.7396	0.02	23.5727	1.99E-01	0.9958	0.0005
MCT008-03	0.1741	0.5073	0.3579	0.4966	0.1689	0.1851	0.1471	3.7669	0.02	23.588	1.42E-01	0.9978	0.0005
MCT008-04	0.1723	0.4998	0.3519	0.4832	0.1429	0.1715	0.1351	4.6486	0.02	23.6031	1.19E-01	1.0021	0.0005
MCT008-05	0.1693	0.4880	0.3429	0.4693	0.1072	0.1535	0.1237	6.5336	0.02	23.5994	9.67E-02	1.0032	0.0005
MCT008-06	0.1663	0.4805	0.3383	0.4622	0.0992	0.1473	0.1215	7.3056	0.02	23.5727	9.17E-02	1.0026	0.0006
MCT008-07	0.1879	0.4035	0.3004	0.4418	0.1184	0.1326	0.1292	3.7669	0.02	23.588	1.41E-01	0.998	0.0005
MCT008-08	0.1865	0.4257	0.3142	0.4556	0.1288	0.1419	0.1329	3.7669	0.02	23.588	1.41E-01	0.9954	0.0007
MCT008-09	0.1839	0.4140	0.3048	0.4482	0.1255	0.1404	0.1333	3.7669	0.02	23.588	1.42E-01	0.9955	0.0006
MCT008-10	0.1827	0.4230	0.3112	0.4518	0.1307	0.1431	0.1330	3.7669	0.02	23.588	1.42E-01	0.9944	0.0006
MCT008-11	0.2023	0.3234	0.2594	0.3808	0.0902	0.0911	0.1105	3.7669	0.02	23.588	1.42E-01	0.9944	0.0005
MCT008-12	0.2044	0.3354	0.2680	0.3906	0.0946	0.0947	0.1126	3.7669	0.02	23.588	1.42E-01	0.9931	0.0005
MCT008-13	0.2023	0.3194	0.2570	0.3762	0.0883	0.0888	0.1085	3.7669	0.02	23.588	1.41E-01	0.9951	0.0005
MCT008-14	0.2040	0.3318	0.2662	0.3865	0.0938	0.0928	0.1107	3.7669	0.02	23.588	1.42E-01	0.9947	0.0005
MCT008-15	0.2042	0.3336	0.2672	0.3874	0.0931	0.0930	0.1098	3.7669	0.02	23.588	1.42E-01	0.9943	0.0005

Table B.2 (continued)

Experiment	E_{sum} for AOA 3-1	E_{sum} for AOA 3-2	E_{sum} for AOA 3-3	E_{sum} for AOA 4-1	E_{sum} for AOA 4-2	E_{sum} for AOA 4-3	E_{sum} for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
MCT008-16	0.2020	0.3355	0.2678	0.3895	0.0960	0.0953	0.1130	3.7669	0.02	23.588	1.42E-01	0.9935	0.0005
MCT008-17	0.2008	0.3311	0.2645	0.3853	0.0951	0.0942	0.1114	3.7669	0.02	23.588	1.43E-01	0.9948	0.0005
MCT008-18	0.2018	0.3257	0.2607	0.3822	0.0907	0.0921	0.1104	3.7669	0.02	23.588	1.42E-01	0.9931	0.0006
MCT008-19	0.2007	0.3319	0.2643	0.3868	0.0944	0.0951	0.1122	3.7669	0.02	23.588	1.42E-01	0.9942	0.0005
MCT008-20	0.2028	0.3287	0.2632	0.3853	0.0931	0.0931	0.1129	3.7669	0.02	23.588	1.43E-01	0.9933	0.0005
MCT008-21	0.2001	0.3293	0.2626	0.3849	0.0939	0.0946	0.1120	3.7669	0.02	23.588	1.43E-01	0.9937	0.0005
MCT008-22	0.2036	0.3409	0.2716	0.3944	0.0975	0.0971	0.1131	3.7669	0.02	23.588	1.43E-01	0.9934	0.0005
MCT008-23	0.2024	0.3295	0.2630	0.3856	0.0921	0.0937	0.1112	3.7669	0.02	23.588	1.43E-01	0.9936	0.0006
MCT008-24	0.1997	0.3341	0.2657	0.3877	0.0964	0.0961	0.1125	3.7669	0.02	23.588	1.43E-01	0.993	0.0005
MCT008-25	0.2014	0.3254	0.2604	0.3818	0.0912	0.0922	0.1104	3.7669	0.02	23.588	1.43E-01	0.9941	0.0005
MCT008-26	0.1995	0.3246	0.2596	0.3804	0.0930	0.0928	0.1103	3.7669	0.02	23.588	1.43E-01	0.9934	0.0006
MCT008-27	0.2015	0.3186	0.2561	0.3762	0.0890	0.0895	0.1093	3.7669	0.02	23.588	1.43E-01	0.9927	0.0006
MCT008-28	0.1999	0.3196	0.2558	0.3763	0.0890	0.0904	0.1092	3.7669	0.02	23.588	1.43E-01	0.9931	0.0006
MCT009-01	0.1575	0.4533	0.3225	0.5470	0.3203	0.2535	0.2713	1.4103	0.015	7.8651	5.52E-01	0.9945	0.0005
MCT009-02	0.1779	0.4864	0.3493	0.5361	0.2531	0.2238	0.2100	1.8685	0.015	7.8647	3.08E-01	0.9923	0.0005
MCT009-03	0.1801	0.5117	0.3603	0.5069	0.1813	0.1998	0.1514	3.0167	0.015	7.8643	1.57E-01	0.9956	0.0005
MCT009-04	0.1776	0.4870	0.3446	0.4750	0.1423	0.1735	0.1290	4.0995	0.015	7.8643	1.18E-01	0.9969	0.0006
MCT009-05	0.1788	0.4497	0.3230	0.4476	0.1062	0.1460	0.1148	5.4541	0.015	7.8643	9.61E-02	0.9998	0.0005
MCT009-06	0.1754	0.4744	0.3331	0.4592	0.1047	0.1564	0.1152	5.8916	0.015	7.8647	9.06E-02	0.9913	0.0006
MCT011-01	0.3285	0.7612	0.6491	0.6478	0.2577	0.1357	0.1185	11.7459	0.2573	9.7532	5.66E-01	1.0023	0.0006
MCT011-02	0.3356	0.7722	0.6651	0.6538	0.2673	0.1347	0.1177	11.7459	0.2573	9.7532	5.55E-01	1.0033	0.0006
MCT011-03	0.3464	0.7883	0.6812	0.6735	0.2744	0.1369	0.1239	11.7459	0.2573	9.7532	5.35E-01	1.0011	0.0006
MCT011-04	0.2932	0.7275	0.6121	0.6123	0.1902	0.1204	0.1028	21.1287	0.2573	9.7532	2.50E-01	1.0018	0.0006
MCT011-05	0.2937	0.7178	0.6071	0.6072	0.1905	0.1180	0.1014	21.1287	0.2573	9.7532	2.57E-01	1.0009	0.0005
MCT011-06	0.2940	0.7181	0.6088	0.6108	0.1946	0.1187	0.1026	21.1287	0.2573	9.7532	2.64E-01	1.0007	0.0006
MCT012-01	0.1702	0.5238	0.3677	0.5021	0.2059	0.2123	0.1416	39.5351	0.0758	23.0093	1.39E-01	0.9784	0.0006
MCT012-02	0.1712	0.5252	0.3680	0.5030	0.2037	0.2130	0.1400	39.5351	0.0758	23.0093	1.39E-01	0.9788	0.0006
MCT012-03	0.1714	0.5260	0.3685	0.5036	0.2029	0.2129	0.1401	39.5351	0.0758	23.0093	1.39E-01	0.9753	0.0005

Table B.2 (continued)

Experiment	E_{sum} for AOA 3-1	E_{sum} for AOA 3-2	E_{sum} for AOA 3-3	E_{sum} for AOA 4-1	E_{sum} for AOA 4-2	E_{sum} for AOA 4-3	E_{sum} for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
MCT012-04	0.1709	0.5246	0.3683	0.5022	0.2058	0.2119	0.1403	39.5351	0.0758	23.0093	1.40E-01	0.9789	0.0007
MCT012-05	0.1708	0.5243	0.3681	0.5021	0.2053	0.2120	0.1405	39.5351	0.0758	23.0093	1.39E-01	0.9784	0.0006
MCT012-06	0.1703	0.5225	0.3684	0.4998	0.2069	0.2094	0.1400	39.5351	0.0758	23.0093	1.40E-01	0.9833	0.0005
MCT012-07	0.1787	0.5170	0.3662	0.4613	0.1271	0.1677	0.0956	101.7127	0.0788	8.1493	6.66E-02	1.0366	0.0006
MCT012-08	0.1790	0.5195	0.3684	0.4642	0.1281	0.1680	0.0976	101.7127	0.0788	8.1493	6.64E-02	1.0329	0.0006
MCT012-09	0.1770	0.5151	0.3627	0.4614	0.1243	0.1693	0.0966	101.7127	0.0788	8.1493	6.62E-02	1.0298	0.0006
MCT012-10	0.1762	0.5122	0.3607	0.4584	0.1232	0.1680	0.0958	101.7127	0.0788	8.1493	6.62E-02	1.0293	0.0006
MCT012-11	0.1782	0.5167	0.3649	0.4618	0.1248	0.1682	0.0958	101.7127	0.0788	8.1493	6.63E-02	1.0285	0.0006
MCT012-12	0.1777	0.5159	0.3643	0.4601	0.1251	0.1678	0.0953	101.7127	0.0788	8.1493	6.63E-02	1.0298	0.0006
MCT012-13	0.1775	0.5147	0.3638	0.4590	0.1253	0.1674	0.0949	101.7127	0.0788	8.1493	6.66E-02	1.0388	0.0006
MCT012-14	0.2011	0.5967	0.4405	0.5392	0.2182	0.1957	0.1276	60.6277	0.1461	8.0016	1.43E-01	1.0239	0.0006
MCT012-15	0.2004	0.5951	0.4388	0.5395	0.2189	0.1973	0.1295	60.6277	0.1461	8.0016	1.43E-01	1.0234	0.0006
MCT012-16	0.2018	0.5992	0.4423	0.5422	0.2173	0.1963	0.1291	60.6277	0.1461	8.0016	1.41E-01	1.0202	0.0007
MCT012-17	0.2043	0.6043	0.4481	0.5478	0.2202	0.1957	0.1313	60.6277	0.1461	8.0016	1.41E-01	1.0215	0.0007
MCT012-18	0.1998	0.5954	0.4374	0.5397	0.2146	0.1976	0.1294	60.6277	0.1461	8.0016	1.40E-01	1.0187	0.0007
MCT012-19	0.2010	0.5987	0.4393	0.5439	0.2133	0.1986	0.1313	60.6277	0.1461	8.0016	1.39E-01	1.0182	0.0006
MCT012-20	0.1878	0.5745	0.4290	0.5154	0.2532	0.1977	0.1289	60.6277	0.1461	8.0016	1.98E-01	1.0185	0.0007
MCT012-21	0.1870	0.5731	0.4274	0.5148	0.2535	0.1982	0.1297	60.6277	0.1461	8.0016	1.98E-01	1.0175	0.0006
MCT012-22	0.0900	0.3261	0.2016	0.3791	0.2034	0.2227	0.1361	60.6277	0.1461	8.0016	2.06E-01	1.0142	0.0007
MCT012-23	0.2109	0.6205	0.4637	0.5514	0.2259	0.1931	0.1261	95.4106	0.3001	8.1648	1.66E-01	1.0132	0.0007
MCT012-24	0.2135	0.6229	0.4677	0.5551	0.2265	0.1915	0.1278	95.4106	0.3001	8.1648	1.65E-01	1.0142	0.0006
MCT012-25	0.2097	0.6205	0.4650	0.5523	0.2297	0.1930	0.1288	95.4106	0.3001	8.1648	1.64E-01	1.0132	0.0006
MCT012-26	0.2120	0.6258	0.4683	0.5568	0.2259	0.1930	0.1276	95.4106	0.3001	8.1648	1.61E-01	1.0116	0.0007
MCT012-27	0.2118	0.6231	0.4636	0.5572	0.2208	0.1946	0.1292	95.4106	0.3001	8.1648	1.60E-01	1.0119	0.0007
MCT012-28	0.2107	0.6226	0.4635	0.5583	0.2237	0.1958	0.1310	95.4106	0.3001	8.1648	1.59E-01	1.0142	0.0006
MCT012-29	0.2101	0.6232	0.4639	0.5569	0.2220	0.1950	0.1284	95.4106	0.3001	8.1648	1.58E-01	1.0131	0.0008
MCT012-30	0.2099	0.6191	0.4596	0.5539	0.2201	0.1952	0.1282	95.4106	0.3001	8.1648	1.60E-01	1.0128	0.0006
MCT012-31	0.1959	0.5968	0.4533	0.5235	0.2700	0.1940	0.1278	95.4106	0.3001	8.1648	2.49E-01	0.9975	0.0007
MCT012-32	0.1960	0.5966	0.4534	0.5219	0.2681	0.1926	0.1255	95.4106	0.3001	8.1648	2.49E-01	0.9984	0.0008
MCT012-33	0.1962	0.5974	0.4541	0.5226	0.2688	0.1927	0.1265	95.4106	0.3001	8.1648	2.49E-01	0.9956	0.0007

Table B.2 (continued)

Experiment	E_{sum} for AOA 3-1	E_{sum} for AOA 3-2	E_{sum} for AOA 3-3	E_{sum} for AOA 4-1	E_{sum} for AOA 4-2	E_{sum} for AOA 4-3	E_{sum} for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
MMF011-01	0.2962	0.3752	0.5178	0.4168	0.4726	0.1010	0.3835	0	0.414	6.16	2.79E+05	1.0009	0.0005
MMF011-02	0.2502	0.3178	0.4402	0.3604	0.4242	0.0955	0.3607	0	0.274	6.73	3.18E+05	1.0059	0.0005
MMF011-03	0.1672	0.2193	0.3021	0.2741	0.3394	0.0808	0.3003	0	0.178	7.88	2.07E+05	1.0088	0.0005
MMF011-04	0.0635	0.0825	0.1154	0.1340	0.1859	0.0513	0.1695	0	0.077	11.6	2.57E+05	1.0097	0.0006
MST001-01	0.1813	0.5746	0.4082	0.5132	0.2162	0.2121	0.1190	46.4302	0.2186	8.3098	1.61E-01	0.9969	0.0006
MST001-02	0.1806	0.5741	0.4076	0.5133	0.2173	0.2123	0.1195	46.2535	0.2196	8.31	1.62E-01	0.9966	0.0006
MST001-03	0.1892	0.5851	0.4214	0.5192	0.2203	0.2069	0.1163	46.2873	0.2213	8.3097	1.58E-01	0.9919	0.0006
MST001-04	0.1759	0.5636	0.3981	0.5067	0.2204	0.2152	0.1204	45.211	0.2216	8.338	1.71E-01	0.9973	0.0006
MST001-05	0.1734	0.5583	0.3926	0.5095	0.2238	0.2207	0.1270	44.1552	0.2214	8.3383	1.76E-01	1.0002	0.0006
MST001-06	0.1906	0.5905	0.4251	0.5224	0.2230	0.2084	0.1193	44.0763	0.2216	8.338	1.69E-01	0.999	0.0006
MST001-07	0.1957	0.6311	0.4618	0.5413	0.2585	0.2102	0.1246	110.439	0.9678	7.94	2.84E-01	1.0005	0.0006
MST001-08	0.1920	0.5950	0.4281	0.5026	0.1968	0.1940	0.0977	213.2237	0.9666	7.9399	1.49E-01	1.0032	0.0006
MST001-09	0.1890	0.5633	0.3986	0.4740	0.1499	0.1798	0.0842	418.636	0.962	7.9402	9.25E-02	1.003	0.0006
MST001-10	0.1776	0.5480	0.3851	0.4835	0.1792	0.1987	0.1021	72.9965	0.2273	8.3378	1.16E-01	1.0025	0.0006
MST001-11	0.1721	0.5380	0.3738	0.4803	0.1736	0.2028	0.1055	72.0147	0.2273	8.3379	1.12E-01	1.0076	0.0007
MST001-12	0.1760	0.5477	0.3838	0.4835	0.1749	0.1991	0.1044	71.5816	0.2278	8.3381	1.09E-01	1.0086	0.0006
MST001-13	0.1739	0.5230	0.3618	0.4590	0.1426	0.1874	0.0911	116.3487	0.2255	8.3378	8.42E-02	1	0.0005
MST002-01	0.1577	0.4518	0.3093	0.4022	0.0563	0.1321	0.0740	1129.223	0.5181	8.3119	4.25E-02	1.0071	0.0006
MST002-02	0.1589	0.4559	0.3112	0.4055	0.0549	0.1331	0.0743	1150.656	0.5211	8.312	4.24E-02	1.0072	0.0006
MST002-03	0.1589	0.4554	0.3110	0.4078	0.0596	0.1365	0.0762	481.3749	0.229	8.3119	4.34E-02	1.0066	0.0005
MST004-01	0.2081	0.5968	0.4425	0.4975	0.1566	0.1604	0.0780	238.9425	0.3968	8.3101	7.15E-02	1.0011	0.0008
MST004-02	0.2024	0.5715	0.4145	0.4791	0.1374	0.1623	0.0778	237.6855	0.3969	8.3099	6.75E-02	1.0013	0.0005
MST004-03	0.1852	0.5409	0.3807	0.4577	0.1264	0.1690	0.0780	238.0412	0.3969	8.31	7.01E-02	1.003	0.0006
MST004-04	0.1904	0.5971	0.4341	0.5156	0.2258	0.2007	0.1108	78.8473	0.4056	8.3098	1.76E-01	1.0024	0.0007
MST004-05	0.2102	0.6247	0.4652	0.5341	0.2271	0.1925	0.1054	78.3251	0.4053	8.3098	1.60E-01	0.9961	0.0006
MST004-06	0.2354	0.6616	0.5113	0.5626	0.2606	0.1875	0.1064	78.5445	0.4052	8.3101	1.93E-01	0.9955	0.0007
MST004-07	0.2196	0.6772	0.5261	0.5918	0.3172	0.2035	0.1372	49.142	0.3964	8.3098	3.54E-01	0.9966	0.0007
MST004-08	0.2116	0.6453	0.4856	0.5635	0.2773	0.2073	0.1293	49.1257	0.3969	8.3101	2.68E-01	0.9966	0.0006

Table B.2 (continued)

Experiment	E_{sum} for AOA 3-1	E_{sum} for AOA 3-2	E_{sum} for AOA 3-3	E_{sum} for AOA 4-1	E_{sum} for AOA 4-2	E_{sum} for AOA 4-3	E_{sum} for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
MST004-09	0.1921	0.6508	0.4901	0.5739	0.2944	0.2111	0.1351	48.9859	0.3972	8.31	3.09E-01	0.9988	0.0007
MST005-01	0.1945	0.5588	0.3998	0.4692	0.1349	0.1667	0.0786	241.4437	0.395	8.31	7.14E-02	0.9967	0.0007
MST005-02	0.1804	0.5309	0.3703	0.4553	0.1175	0.1693	0.0810	238.4842	0.3981	8.3099	6.70E-02	1.0029	0.0007
MST005-03	0.1898	0.5928	0.4257	0.5168	0.2098	0.2040	0.1105	78.8898	0.4066	8.3102	1.55E-01	1.0021	0.0008
MST005-04	0.1921	0.5981	0.4316	0.5216	0.2093	0.2012	0.1125	78.8898	0.4066	8.3102	1.53E-01	0.9992	0.0006
MST005-05	0.2002	0.6160	0.4569	0.5285	0.2416	0.1984	0.1127	78.5768	0.4062	8.3098	1.95E-01	0.9892	0.0007
MST005-06	0.1977	0.6303	0.4713	0.5544	0.2980	0.2149	0.1425	49.0373	0.3966	8.3099	3.56E-01	0.9875	0.0007
MST005-07	0.1957	0.6210	0.4523	0.5553	0.2560	0.2170	0.1365	49.0069	0.3964	8.3099	2.54E-01	0.9976	0.0006
NSE55T4-01	0.1969	0.5847	0.4270	0.5310	0.2098	0.1983	0.1273	30.6	0.146	7.97	1.43E-01	1.0179	0.0006
NSE55T4-02	0.1906	0.5785	0.4182	0.5275	0.2094	0.2029	0.1286	30.6	0.146	7.97	1.46E-01	1.0187	0.0006
NSE55T4-03	0.1888	0.5745	0.4148	0.5239	0.2098	0.2032	0.1271	30.6	0.146	7.97	1.47E-01	1.0175	0.0007
NSE55T4-04	0.1869	0.5708	0.4102	0.5240	0.2112	0.2068	0.1307	30.6	0.146	7.97	1.49E-01	1.0182	0.0006
NSE55T4-05	0.1837	0.5652	0.4044	0.5183	0.2110	0.2082	0.1291	30.6	0.146	7.97	1.50E-01	1.0176	0.0006
NSE55T4-06	0.1849	0.5687	0.4080	0.5225	0.2151	0.2094	0.1317	30.6	0.146	7.97	1.51E-01	1.0174	0.0006
NSE55T4-07	0.1858	0.5664	0.4062	0.5187	0.2096	0.2059	0.1288	30.6	0.146	7.97	1.51E-01	1.0208	0.0006
NSE55T4-08	0.1799	0.5585	0.3970	0.5140	0.2124	0.2119	0.1305	30.6	0.146	7.97	1.53E-01	1.0181	0.0007
NSE55T4-09	0.1999	0.5842	0.4248	0.5306	0.2051	0.1992	0.1262	30.6	0.146	7.97	1.43E-01	1.0186	0.0005
NSE55T4-10	0.1953	0.5824	0.4223	0.5303	0.2073	0.2014	0.1280	30.6	0.146	7.97	1.43E-01	1.0184	0.0006
NSE55T4-11	0.1960	0.5830	0.4236	0.5311	0.2083	0.2010	0.1287	30.6	0.146	7.97	1.43E-01	1.0193	0.0006
NSE55T4-12	0.1879	0.5817	0.4223	0.5316	0.2113	0.2020	0.1296	30.6	0.146	7.97	1.43E-01	1.0192	0.0006
NSE55T4-13	0.1979	0.5770	0.4178	0.5235	0.2058	0.2008	0.1254	30.6	0.146	7.97	1.46E-01	1.0188	0.0006
NSE55T4-14	0.1862	0.5689	0.4067	0.5211	0.2087	0.2077	0.1287	30.6	0.146	7.97	1.51E-01	1.0213	0.0006
NSE55T4-15	0.1853	0.5668	0.4070	0.5169	0.2087	0.2045	0.1272	30.6	0.146	7.97	1.50E-01	1.0211	0.0006
NSE55T4-16	0.1869	0.5692	0.4097	0.5198	0.2086	0.2038	0.1270	30.6	0.146	7.97	1.49E-01	1.0201	0.0006
NSE55T4-17	0.1779	0.5540	0.3909	0.5125	0.2100	0.2153	0.1309	30.6	0.146	7.97	1.54E-01	1.0182	0.0005
NSE55T4-18	0.1772	0.5542	0.3915	0.5136	0.2142	0.2161	0.1340	30.6	0.146	7.97	1.55E-01	1.0161	0.0006
NSE55T4-19	0.1766	0.5534	0.3904	0.5132	0.2144	0.2171	0.1333	30.6	0.146	7.97	1.56E-01	1.0154	0.0006
NSE55T4-20	0.1788	0.5548	0.3921	0.5109	0.2099	0.2135	0.1303	30.6	0.146	7.97	1.58E-01	1.0213	0.0006
NSE55T4-21	0.1912	0.5770	0.4165	0.5262	0.2070	0.2025	0.1270	30.6	0.146	7.97	1.46E-01	1.0528	0.0006
NSE55T4-22	0.1864	0.5669	0.4056	0.5204	0.2060	0.2066	0.1289	30.6	0.146	7.97	1.45E-01	1.0463	0.0006

Table B.2 (continued)

Experiment	E_{sum} for AOA 3-1	E_{sum} for AOA 3-2	E_{sum} for AOA 3-3	E_{sum} for AOA 4-1	E_{sum} for AOA 4-2	E_{sum} for AOA 4-3	E_{sum} for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
NSE55T5-01	0.2477	0.7622	0.6777	0.8521	0.7209	0.2781	0.5433	2.8	0.303	11.5	3.97E+01	1.0058	0.0005
NSE55T5-02	0.2625	0.8089	0.7121	0.8892	0.7178	0.2870	0.5391	2.8	0.303	11.5	3.97E+01	1.0028	0.0005
NSE55T5-03	0.2557	0.7443	0.6593	0.8424	0.6849	0.2674	0.5269	2.8	0.303	11.5	4.00E+01	1.0049	0.0005
NSE55T5-04	0.2496	0.8028	0.6985	0.8847	0.7201	0.2938	0.5520	2.8	0.303	11.5	4.10E+01	1.0048	0.0005
NSE55T5-05	0.2573	0.8033	0.7047	0.8930	0.7318	0.2941	0.5511	2.8	0.303	11.5	4.03E+01	1.002	0.0005
NSE55T5-06	0.2535	0.7750	0.6797	0.8681	0.7178	0.2867	0.5501	2.8	0.303	11.5	4.14E+01	1.0045	0.0005
NSE55T5-07	0.2509	0.7935	0.6990	0.8877	0.7465	0.2909	0.5652	2.8	0.303	11.5	4.39E+01	1.0042	0.0005
NSE55T5-08	0.2594	0.7802	0.6851	0.8720	0.7037	0.2857	0.5389	2.8	0.303	11.5	3.93E+01	1.0026	0.0006
NSE55T5-09	0.2473	0.7587	0.6621	0.8321	0.6600	0.2656	0.5099	2.8	0.303	11.5	3.88E+01	1.0023	0.0005
NSE55T5-10	0.2548	0.7818	0.6914	0.8724	0.7202	0.2811	0.5415	2.8	0.303	11.5	3.85E+01	1.0036	0.0004
PCI001-01	0.0209	0.5084	0.3747	0.5904	0.6151	0.2616	0.5166	0.37	1	5.3	3.08E+02	0.9988	0.0001
PCM001-01	0.1913	0.1638	0.2349	0.1662	0.1575	0.0208	0.0832	0.04	1	18.35	9.57E+05	1.0261	0.0007
PCM001-02	0.2287	0.8390	0.8465	0.7670	0.6971	0.1936	0.4677	5	1	11.46	1.73E+03	1.0198	0.0007
PCM001-03	0.3157	0.8130	0.7400	0.7303	0.6039	0.2068	0.3392	15	1	2.2	3.26E+01	1.0168	0.0008
PCM001-04	0.1365	0.7921	0.7004	0.7367	0.6271	0.2159	0.3713	15	1	8.06	3.95E+01	0.9878	0.0007
PCM001-05	0.1815	0.6347	0.4855	0.5623	0.3754	0.2151	0.1881	49.6	1	18.35	1.54E+00	1.0087	0.0007
PCM002-01	0.3900	0.6894	0.7794	0.5933	0.4266	0.1311	0.3035	0.04	1	18.35	4.92E+03	1.0322	0.0007
PCM002-02	0.3890	0.6735	0.7603	0.5876	0.4030	0.1215	0.2786	0.04	1	18.35	4.21E+03	1.0308	0.0006
PCM002-03	0.3903	0.7194	0.7988	0.6210	0.4199	0.1359	0.3021	0.04	1	18.35	3.51E+03	1.0262	0.0006
PCM002-04	0.3775	0.6889	0.7686	0.5980	0.4115	0.1297	0.2950	0.04	1	18.35	2.57E+03	1.0197	0.0006
PCM002-05	0.3460	0.6480	0.7216	0.5652	0.3722	0.1123	0.2694	0.04	1	18.35	1.87E+03	1.0171	0.0006
PCM002-06	0.4621	0.8709	0.8484	0.7942	0.5649	0.1862	0.3824	5	1	11.46	9.25E+01	1.0234	0.0006
PCM002-07	0.2049	0.7835	0.7384	0.7261	0.5222	0.1747	0.3673	5	1	11.46	8.49E+01	1.022	0.0006
PCM002-08	0.5212	0.8977	0.8775	0.8057	0.5726	0.1966	0.3872	5	1	11.46	6.80E+01	1.0212	0.0006
PCM002-09	0.1453	0.7341	0.7124	0.6688	0.4684	0.1664	0.3189	5	1	11.46	5.68E+01	1.0218	0.0005
PCM002-10	0.3082	0.8321	0.7193	0.7598	0.4740	0.2074	0.2916	15	1	2.2	4.14E+00	1.0306	0.0006
PCM002-11	0.3074	0.8229	0.7170	0.7534	0.4805	0.2034	0.2924	15	1	2.2	4.55E+00	1.028	0.0006
PCM002-12	0.3174	0.8341	0.7276	0.7646	0.4914	0.2069	0.2966	15	1	2.2	5.13E+00	1.0273	0.0006

Table B.2 (continued)

Experiment	E_{sum} for AOA 3-1	E_{sum} for AOA 3-2	E_{sum} for AOA 3-3	E_{sum} for AOA 4-1	E_{sum} for AOA 4-2	E_{sum} for AOA 4-3	E_{sum} for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
PCM002-13	0.1908	0.5895	0.4953	0.5063	0.2977	0.1428	0.1691	15	1	2.2	5.46E+00	1.0256	0.0006
PCM002-14	0.3252	0.8456	0.7373	0.7687	0.5062	0.2108	0.3042	15	1	2.2	5.60E+00	1.0295	0.0006
PCM002-15	0.3290	0.8431	0.7341	0.7712	0.4792	0.2049	0.2912	15	1	2.2	5.56E+00	1.0283	0.0006
PCM002-16	0.3235	0.8368	0.7358	0.7696	0.5005	0.2053	0.2979	15	1	2.2	5.15E+00	1.0235	0.0007
PCM002-17	0.3380	0.8228	0.7114	0.7610	0.4789	0.2118	0.3044	15	1	2.2	4.93E+00	1.0073	0.0007
PCM002-18	0.3542	0.8460	0.7346	0.7765	0.5032	0.2152	0.3065	15	1	2.2	6.19E+00	1.0102	0.0006
PCM002-19	0.3275	0.8471	0.7371	0.7768	0.5116	0.2126	0.3077	15	1	2.2	6.47E+00	1.0088	0.0006
PCM002-20	0.3507	0.8390	0.7324	0.7671	0.5135	0.2139	0.3046	15	1	2.2	6.65E+00	1.0087	0.0005
PCM002-21	0.1421	0.7838	0.6666	0.7360	0.4922	0.2012	0.3040	15	1	2.2	6.64E+00	1.0101	0.0006
PCM002-22	0.4183	0.8320	0.7216	0.7578	0.4936	0.2109	0.3013	15	1	2.2	6.45E+00	1.0143	0.0007
PCM002-23	0.2130	0.6840	0.5176	0.6169	0.3224	0.2164	0.1827	49.6	1	18.35	6.84E-01	1.0087	0.0006
PCM002-24	0.2142	0.6828	0.5158	0.6114	0.3144	0.2135	0.1755	49.6	1	18.35	6.97E-01	1.0096	0.0006
PCM002-25	0.2076	0.6737	0.5094	0.6062	0.3246	0.2150	0.1821	49.6	1	18.35	7.05E-01	1.0096	0.0006
PCM002-26	0.2123	0.6880	0.5247	0.6131	0.3316	0.2136	0.1785	49.6	1	18.35	7.13E-01	1.0113	0.0006
PCM002-27	0.2057	0.6560	0.4946	0.5897	0.3146	0.2110	0.1745	49.6	1	18.35	7.21E-01	1.011	0.0006
PCM002-28	0.2133	0.6873	0.5272	0.6142	0.3348	0.2112	0.1803	49.6	1	18.35	7.26E-01	1.0099	0.0005
PCM002-29	0.2155	0.6899	0.5292	0.6159	0.3312	0.2110	0.1801	49.6	1	18.35	7.36E-01	1.0117	0.0006
PMF001-01	0.4355	0.6873	0.8440	0.5090	0.4431	0.1463	0.2961	0	1	4.7	1.24E+06	0.9949	0.0007
PMF002-01	0.4301	0.6867	0.8383	0.5093	0.4428	0.1506	0.3009	0	1	20.1	1.26E+06	0.9964	0.0005
PMF003-01	0.4455	0.7570	0.8966	0.5460	0.4633	0.1857	0.3143	0	1	5.97	1.24E+06	0.9937	0.0006
PMF003-02	0.4419	0.7359	0.8790	0.5407	0.4595	0.1734	0.3117	0	1	5.97	6.90E+05	0.9935	0.0007
PMF003-03	0.4424	0.7383	0.8821	0.5369	0.4585	0.1750	0.3102	0	1	5.97	1.24E+06	0.9879	0.0006
PMF003-04	0.3792	0.5173	0.6715	0.4280	0.3967	0.0960	0.2737	0	1	5.97	6.24E+05	0.9926	0.0006
PMF003-05	0.3383	0.3983	0.5495	0.3492	0.3494	0.0654	0.2381	0	1	5.97	1.24E+06	0.9908	0.0007
PMF016-01	0.2803	0.4030	0.4996	0.3622	0.2662	0.0609	0.1774	0	1	5.97	1.17E+04	1.0118	0.0006
PMF016-02	0.3545	0.5149	0.6434	0.4673	0.3504	0.0982	0.2558	0	1	5.97	8.61E+03	1.0003	0.0006
PMF016-03	0.3586	0.5236	0.6519	0.4757	0.3503	0.0990	0.2573	0	1	5.97	8.34E+03	0.9995	0.0007
PMF016-04	0.3311	0.5018	0.6191	0.4549	0.3239	0.0893	0.2360	0	1	5.97	8.01E+03	0.9982	0.0007
PMF016-05	0.1884	0.1788	0.2214	0.2041	0.1278	0.0290	0.1011	0	1	5.97	7.93E+03	0.9965	0.0006
PMF016-06	0.2987	0.3525	0.4820	0.3385	0.2929	0.0615	0.2092	0	1	5.97	7.78E+03	1.0003	0.0007

Table B.2 (continued)

Experiment	E_{sum} for AOA 3-1	E_{sum} for AOA 3-2	E_{sum} for AOA 3-3	E_{sum} for AOA 4-1	E_{sum} for AOA 4-2	E_{sum} for AOA 4-3	E_{sum} for AOA 4-4	H/(Pu + U)	Pu/(Pu + U)	Wt % ^{240}Pu	EALF (eV)	k_{eff}	σ
PMF017-01	0.4412	0.7465	0.8866	0.5507	0.4716	0.1773	0.3241	0	1	5.97	7.82E+05	0.9901	0.0007
PMF017-02	0.4396	0.7643	0.8982	0.5690	0.4859	0.1900	0.3385	0	1	5.97	4.05E+05	0.9932	0.0007
PMF017-03	0.4375	0.7708	0.9012	0.5746	0.4853	0.1903	0.3377	0	1	5.97	2.30E+05	0.994	0.0008
PMF017-04	0.4296	0.7291	0.8712	0.5523	0.4827	0.1757	0.3430	0	1	5.97	4.58E+05	0.991	0.0006
PMF017-05	0.4315	0.7698	0.8927	0.5859	0.4864	0.1785	0.3347	0	1	5.97	9.39E+04	1.002	0.0006
PMF033-01	0.3092	0.3912	0.5358	0.4108	0.4596	0.1000	0.3921	0	1	5.83	4.02E+05	1.0066	0.0005
PMF037-01	0.4383	0.7745	0.8974	0.5871	0.4792	0.1848	0.3292	0	1	5.97	1.48E+05	0.9973	0.0006
PMF037-05	0.4191	0.6922	0.8187	0.5598	0.4480	0.1462	0.3101	0	1	5.97	5.12E+04	0.9977	0.0006
PMF037-07	0.4286	0.7838	0.8835	0.6172	0.4583	0.1661	0.3150	0	1	5.97	3.30E+04	0.9984	0.0006
PMF037-10	0.4022	0.5566	0.6759	0.4996	0.3627	0.0995	0.2631	0	1	5.97	2.61E+04	0.9993	0.0006
PMF037-12	0.3584	0.4796	0.6202	0.4255	0.3654	0.0890	0.2517	0	1	5.97	2.35E+04	1.0009	0.0006
PMF037-15	0.4070	0.7219	0.8284	0.5847	0.4193	0.1424	0.2945	0	1	5.97	1.82E+04	0.9985	0.0005
PMF037-16	0.4014	0.6704	0.7977	0.5464	0.4260	0.1423	0.3058	0	1	5.97	2.84E+04	0.9996	0.0006
PU-15-1	0.1931	0.7103	0.5634	0.8496	0.7191	0.3515	0.5623	2.86	0.15		1.51E+01	0.9811	0.0003
PU-29-1	0.2694	0.8478	0.7412	0.9227	0.7449	0.3028	0.5594	2.77	0.29	11.5	4.14E+01	0.9941	0.0003
PU-29-2	0.2684	0.8485	0.7395	0.9206	0.7419	0.3078	0.5583	2.77	0.29	11.5	4.03E+01	0.9931	0.0005
PU-29-3	0.2677	0.8479	0.7383	0.9187	0.7331	0.3001	0.5529	2.77	0.29	11.5	4.07E+01	1.0022	0.0005
PU-29-4	0.2691	0.8500	0.7406	0.9209	0.7309	0.2995	0.5548	2.77	0.29	11.5	3.78E+01	0.9932	0.0004
PU-29-5	0.2709	0.8545	0.7420	0.9201	0.7231	0.2994	0.5473	2.77	0.29	11.5	3.77E+01	0.9937	0.0003
PU-29-6	0.2657	0.8487	0.7346	0.9157	0.7200	0.3029	0.5472	2.77	0.29	11.5	3.67E+01	0.9931	0.0003
PU-29-7	0.2636	0.8187	0.7159	0.8935	0.7108	0.2897	0.5376	2.77	0.29	11.5	3.48E+01	0.9944	0.0005
PU-29-8	0.2618	0.8140	0.7109	0.8877	0.7027	0.2873	0.5365	2.77	0.29	11.5	3.44E+01	0.9951	0.0005
PU-29-9	0.2597	0.8443	0.7290	0.9086	0.7130	0.3016	0.5457	2.77	0.29	11.5	3.46E+01	0.9987	0.0005
PU-8-1	0.1728	0.5862	0.4224	0.6192	0.3786	0.2734	0.2541	7.33	0.08	11.5	6.45E-01	1.005	0.0006
PU-8-2	0.1718	0.5843	0.4196	0.6178	0.3768	0.2751	0.2542	7.33	0.08	11.5	6.41E-01	1.0036	0.0005
PU-8-3	0.1706	0.5822	0.4168	0.6167	0.3745	0.2768	0.2541	7.33	0.08	11.5	6.38E-01	1.0059	0.0006
PU-8-4	0.1719	0.5847	0.4203	0.6193	0.3783	0.2759	0.2563	7.33	0.08	11.5	6.30E-01	1.0053	0.0006

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